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NAVEDTRA 10206-B
October 1985
0502-LP-051-0300

Rate Training
Manual

Opticalman
1 & C

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STACKS

Although the words "he," "him," and "his" are used sparingly in this manual to enhance communication, they are not intended to be gender driven nor to affront or discriminate against anyone reading *Opticalman 1 & C*, NAVEDTRA 10206-B.

Naval Education And Training Program Development Center

OPTICALMAN 1 & C

NAVEDTRA 10206-B

1985 Edition Prepared by
OMC Lloyd Stagg

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PREFACE

The primary purpose of training is to produce a Navy which can maintain control of the sea and guarantee victory. Victory at sea depends upon the state of readiness of shipboard personnel to perform tasks assigned to them in accordance with the needs of their ship. This rate training manual provides information related to the tasks assigned to Opticalmen First Class and Chief Opticalmen who maintain rangefinders, gunsights, telescopes, submairne periscopes, and other optical instruments. It also discusses management of MIRCS facilities and the use of optical alignment equipment.

Only when shipboard personnel can and do perform their tasks efficiently, will each ship contribute to victory at sea. As an OM1 or OMC, you will be expected to know the information contained in this manual and to perform your assigned tasks. The NRCC provides the means for satisfying the requirements for completing this RTM.

This self-study package was prepared by the Naval Education and Training Program Development Center, Pensacola, Florida, for the Chief of Naval Education and Training.

Technical assistance was provided by the Service School Command (OM School), Great Lakes, Illinois, Naval Sea Systems Command, Washington, D.C.

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THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends; the United States Navy exists to make it so.

WE SERVE WITH HONOR

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us; our adversities strengthen us.

Service to God and Country is our special privilege. We serve with honor.

THE FUTURE OF THE NAVY

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy. The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.

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38985	PREPARE AND MAINTAIN RECORDS, LOGS, REPORTS AND WORK REQUESTS	NAVEDTRA 10858-F
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CHAPTER 1

OPTICALMEN AND THEIR WORK

At this stage in your naval career, you are well aware that training on a continuous basis is essential. This training is needed if you are to reach your desired goals and if the mission of the Navy is to be successfully accomplished. This manual is one of many sources of information you will need to continue your training. It will help you become proficient in the tasks you will perform at the E-6 and E-7 levels. Knowledge of the information contained in this manual, combined with everyday practical experience, will help you perform assigned tasks successfully and accept ever greater responsibilities.

MILITARY DUTIES AND RESPONSIBILITIES

Anytime you are promoted, you as well as the Navy benefit. The fact that you are using this training manual indicates that you find personal satisfaction in developing your skills. This development increases your knowledge and allows you to get ahead in your chosen career. The Navy benefits from your efforts. It will continue to benefit as you become more skilled as a technical specialist in the Optical rating and as a person who can supervise and train others. The Navy also benefits from your efforts and will continue to do so as you become more skilled as a technical specialist in the Optical rating and as a person who can supervise and train others. Your contribution to the Navy will depend upon your willingness and ability to accept increasing responsibilities as you advance.

When you assumed the duties of an OM3, the Navy rewarded you with an increase in pay and provided you with added responsibilities. As you advance in rate, you must accept more responsibilities in military matters and in matters relating to the repair of optical equipment that comes to your shop.

CHAIN OF COMMAND

Your responsibilities for military leadership are similar to those of petty officers in other ratings. Every petty officer is both a military person and a technical specialist. Your responsibilities for technical leadership are specific to your rating and are directly related to the nature of your work.

OMs are responsible for overhauling, repairing, and maintaining optical instruments and navigation equipment. These jobs are of vital importance to the Navy. Most of your assignments will require some amount of teamwork as well as special technical skills. These skills can only be developed by a dedicated effort, a high degree of competency, and a deep sense of pride and responsibility. Your responsibilities for administration, supervision, and training are discussed later in this chapter. Now let us consider some aspects of your increasing responsibilities for military and technical leadership.

Your responsibilities extend both upward and downward in the chain of command. Supervisors expect you to carry out their orders. Junior and inexperienced personnel expect you to translate the general orders given by superiors into detailed, practical, on-the-job language they can understand. In dealing with junior personnel, you will be responsible for ensuring they perform their work properly. At the same time, you will be expected to explain to your superiors any important need or problem related to your junior personnel.

TRAINING

You will have regular and continuing responsibilities for training. Even if you are fortunate enough to have a highly skilled and well-trained group working for you, you will still find that additional training must be provided. For example, you will be expected to train lower rated personnel. This is especially true when some of your best workers are transferred, discharged, or replaced by new A and or C school graduates. As a training specialist, you will be responsible for training individuals and groups to perform their assigned tasks effectively.

COORDINATION

You will have increasing responsibilities in working with others. You will find that many of your plans and decisions will affect a large number of people. Some of those affected may not even be in your optical shop, division, or aboard your ship. Therefore, understanding the duties and responsibilities of personnel in other ratings becomes increasingly important. All petty officers in the Navy are technical specialists in their own fields. Learn as much as you can about the work of other ratings, and plan your own work to fit in with the overall mission of your department.

COMMUNICATION

As your responsibilities will increase, your ability to communicate clearly and effectively must also increase. The basic requirement for effective communication is a knowledge of your own language. Use correct language in speaking and in writing. Remember that the basic function of all communication is understanding. To lead, supervise, and train others, you must be able to speak and write in such a way that others can understand exactly what you mean.

A second requirement for effective communication in the Navy is a sound knowledge of the Navy way of saying things. Some Navy terms have been standardized to ensure efficient communication. When a situation calls for the use of standard Navy terminology, you should use it.

Another requirement for effective communication is the precise use of technical terms. The correct use of technical terms among your peers is important. It is even more important when you deal with lower rated personnel. Misuse of technical terms is extremely confusing and frustrating to the inexperienced person. Command of the technical language of the Opticalman rating allows you to exchange ideas with other OM personnel. Personnel who do not understand the precise meaning of terms related to their own rating are at a disadvantage when they try to read technical and official publications. They are at an even greater disadvantage when they take the written examinations for advancement.

NEW DEVELOPMENTS

You will have increased responsibilities for keeping up with new developments. Practically everything in the Navy—policies, procedures, equipment, publications, systems—is subject to change and new development. As an OM1, and even more as an OMC, you must keep yourself informed about all these changes and developments that affect either your rating or your work.

Some changes will be called directly to your attention; others you will have to look for. You must develop a special kind of alertness for new information and keep up to date on all sources of technical information. Information on sources of primary concern to the Opticalman is given later in this chapter.

As you prepare to assume increased responsibilities at a higher level, you will need to be familiar with (1) the military requirements and occupational standards given in the *Manual of Navy Enlisted Manpower and Personnel Classifications and Occupational Standards*, NAVPERS 18068 (with changes); (2) the *Personnel Advancement Requirements* (PAR), NAVPERS 1414/4; (3) appropriate rate training manuals; and (4) any other material that may be required or recommended in the most current edition of the *Bibliography for Advancement Study*, NAVEDTRA 10052. These materials and their uses are discussed more thoroughly in *Military Requirements for Petty Officer First Class*, NAVEDTRA 10046, *Military Requirements for Chief Petty Officer*, NAVEDTRA 10047, and *Opticalman 3 & 2*, NAVEDTRA 10205-C, and other publications that will be described later in this chapter.

YOUR JOB AS AN OPTICALMAN

Since the time you first became a designated striker, you have mastered some basic skills. You have become familiar with much of the terminology related to the repairing of navigation instruments and other optical equipment. You have also gained enough experience to be able to answer many of the questions asked by less experienced personnel. The rate for which you are now preparing demands more knowledge and skill, a willingness to assume greater responsibilities, and the ability to delegate work.

As an OM, you must become familiar with the functions of your division. As an OMC, you must become familiar with the activities of the whole repair department and proficient in a wide variety of tasks. As an OMC, you may also be expected to supervise the instrument shops. Your duties will include the use of proper procedures for troubleshooting, maintenance and repair, planning, organizing, and in carrying out all work assigned. You will maintain records and submit reports. You will supervise the stowage of supplies and repair parts. You will take an active part in the training of lower rated personnel. In brief, you will become a technical specialist and a military leader.

ASSIGNMENTS

An Opticalman is generally assigned sea duty in the optical shops on repair ships and tenders. Occasionally you may be assigned to a shore based optical shop. This shop is part of a ship's intermitted maintenance activity (SIMA) or submarine support facility. In an optical shop, you will repair and maintain advanced optical systems of range finders, submarine periscopes, night vision equipment, gunsight telescopes, and other optical instruments. As optics and electronics become more intertwined, you not only will be expected to learn the theory of light, but also some basic electricity.

Other shore duty for Opticalman 1 & C may include recruiting or instructing at an OM/IM school on a naval reserve training center. In addition, a billet for a Chief Opticalman is located at the Naval Education and Training Program Development Center (NETPDC), Pensacola, Florida. Navy-wide advancement examinations, rate training manuals, correspondence courses, and other training materials are written and revised at NETPDC.

DUTIES AND RESPONSIBILITIES IN THE REPAIR DEPARTMENT

An Opticalman First Class or Chief Opticalman must have a thorough understanding of the repair department and the organization and administration of its divisions.

The primary function of a repair department is the repair and maintenance of ships (and equipment) that are assigned by higher authority. A secondary mission is the repair of its own ship's machinery and equipment. When your assignment sends you to duty ashore, you will work within the framework of an organization with a mission similar to a shipboard repair department.

A department is the backbone of the organizational structure of the ship. The functions of a department are limited to certain clearly defined activities, such as those related to engineering, repair, or gunnery. This organizational structure permits the commanding officer to delegate responsibilities to lower levels of authority. However, it allows him to maintain overall control and responsibility for the operation of the ship.

A department is subdivided into divisions with respect to smaller areas of responsibility within the department. The head of a department is responsible to the commanding officer for the operation of the department. Departmental and divisional assistants are responsible to the head of the department.

As an Opticalman and a supervisor, you will be concerned with the organization of the repair department and its divisions. The structure is basically the same for all types of repair ships. The assignment of optical shops depends on the locations of the divisions. Some are located in the Atlantic or Pacific fleet and some on submarine tenders (AS), destroyer tenders (AD), or repair ships (AR).

REPAIR OFFICER

The repair officer is the head of the repair department. His primary responsibility is to maintain a well-organized and efficient repair department. To accomplish this, the repair officer issues and enforces departmental orders and makes frequent inspections to ensure the maintenance of proper standards within the department. The repair officer reviews personnel problems in such matters as training, assignments, and leave. He is responsible for the department's operation within the allotment granted and for the request of additional funds when necessary.

The repair officer reviews work requests received, and when required, makes recommendations to the commanding officer regarding the acceptance or rejection of specific jobs. These recommendations are made according to the capabilities and current work load of the repair department.

ASSISTANT REPAIR OFFICER

The assistant repair officer is charged with the responsibilities of the repair officer in the latter's absence. Otherwise he performs such duties as may be delegated by the repair officer. The assistant repair officer, charged with the internal administration of the repair department, handles department correspondence, maintains files and records, and prepares reports. He is responsible for the details of the training program for personnel in the repair department. The routing of work requests and the dissemination of any information (such as department orders) necessary to the welfare of personnel are also done by the assistant repair officer.

In addition to general office administration, the assistant repair officer may be assigned more specific jobs. These jobs include keeping progress data on all outstanding work, supervising the technical library, assigning ship's supervisors, and preparing requisitions for special material. When performing this latter function, the assistant repair officer will work closely with the supply department to expedite the preparation of requisitions and to initiate follow-up on all outstanding requisitions.

DIVISION OFFICERS

All division officers in the repair department are responsible for the functions of their own divisions.

DUTY REPAIR OFFICER

A duty repair officer is a repair department officer assigned to serve in this capacity from 0800 to 0800 the following day. He assumes the duties of the repair officer and assistant repair officer in their absence. After normal working hours, he frequently inspects repair department working and living spaces. When in port, the duty repair officer makes 2000 reports (8 o'clock reports) to the command duty officer relative to the security of the department, the personnel and the boats away from the ship on repair work, and the approximate time the work center will secure. He reports to the repair officer or to the assistant repair officer prior to 1600 on work days to be briefed about repairs to be accomplished after normal working hours. He is responsible for approving, expediting, and supervising emergency repair work after normal working hours and for calling the repair officer when necessary.

Duty Repair Chief Petty Officer

Each day one chief petty officer from the repair department is assigned the duties of duty repair chief. The tour of duty commences at 0800 and ends at 0800 the following day. As assistant to the duty repair officer, he musters the watch section immediately after quarters to determine whether personnel appointed to watches were instructed concerning their duties. All watches and duties involved are listed in the Repair Department Organization and Regulations Manual. Berthing spaces and repair department spaces are inspected on an as necessary basis (and after normal working hours) for cleanliness, safety, fire hazards, and locked tool cabinets and storerooms. When necessary the duty repair chief must take prompt action and call the division duty petty officers to have the deficiencies corrected. He ensures that duty division petty officers hold reveille promptly. Prior to taps, he reports to the duty repair officer and accompanies him in making inspections of repair department spaces. Deficiencies are corrected on the spot. Unsatisfactory conditions are reported by memorandum to the repair officer.

Duty Division Petty Officer

Each day, one leading petty officer from each division's duty section is assigned as duty division petty officer. On normal work days, the duty division petty officer's tour lasts from the end of the work day until 0800 the following day. On Saturdays, Sundays, and holidays, the tour of duty lasts from 0800 to 0800. The duties of the duty division petty officer include inspection of the division work center spaces at the end of working hours for security, and reports to the duty repair officer at 1600 and 1900 hours concerning the progress of urgent repair work. Additionally, the duty division petty officer ensures that only authorized personnel use machinery and comply with existing orders, instructions, and safety precautions. He also makes certain that no fire or accident hazards exist in berthing and work center spaces, that tools found adrift are returned to toolrooms, and that the toolrooms are locked. In the absence of the work center supervisor, the division petty officer takes charge of the repair work of the division after normal working hours.

SHIP'S SUPERINTENDENT AND REPAIR DEPARTMENT PROGRESSMAN

You may be assigned as ship's superintendent or as a repair department progressman. These jobs require a considerable knowledge of repair procedures to process work requests and maintain logs and reports. The repair officer uses this information to keep up to date on the status of work being done on ships alongside. The responsibilities of a ship's superintendent and a progressman often overlap. Occasionally both functions may be performed at the same time.

Collectively, your duties as a ship's superintendent or progressman will include the following:

1. Acting as coordinator of work on the ships assigned to you and as liaison between the ships and the tender in regard to repair department jobs.
2. Reporting daily to the commanding officers, or their representatives, of the ships assigned to you to ensure that the work is progressing satisfactorily.
3. Reporting on Friday of each week to the repair officer the status of each job, and bringing to his attention any high priority job that is lagging. You will include in this report recommendations regarding shifting of work, material procurement, and your estimation as to whether or not the job can be completed on time.
4. Maintaining a daily progress report or chart indicating (a) the percent of completion of each job; (b) the availability of plans, sketches, or samples; and (c) the availability of material required for each job.
5. Maintaining a follow-up check on material ordered to ensure the timely receipt of the material, and obtaining signatures from the officers concerned in case of cancellation of a work request.
6. Notifying the ships about completed material on the tender, and securing signatures from officers concerned on completion of work requests.
7. Notifying ship's personnel to witness tests on machinery, compartments, and tanks when required.

REPAIR DIVISION WORK CENTER SUPERVISOR

As a leading petty officer, you should know what work is done and what equipment is used by personnel of other engineering and hull group ratings. Many maintenance and repair jobs can be properly handled within your own division. Some jobs require skills and equipment found only in other divisions.

A cooperative attitude is a requisite of good leadership and supervision. You should maintain this attitude when dealing with your personnel and with personnel not assigned to your work center whom you may have to instruct and supervise. Your attitude will have a definite effect upon the attitudes and the actions of these personnel.

As an OM1, you may work with a chief who will assign you to handle the operational routine of the optical shop. The chief will depend on you to help with many tasks and to accept any necessary responsibility. Therefore, you must be prepared to assume complete responsibility for the operation of the shop when required.

Duties of Work Center Supervisor

The leading petty officer in each work center is generally also the work center supervisor. His duties will be yours when you become the leading petty officer in an optical shop. You will then be expected to plan, schedule, and maintain (under supervision of the division officer) the work center work load. Your function will be to expedite the completion of work requested, and to ensure by frequent inspections that all repairs are accomplished in a timely and satisfactory manner. You will advise your division officer relative to production lags and make recommendations on requests submitted by your subordinates. You will maintain order and discipline in the work center and ensure that work center equipment is cared for and kept clean and in excellent condition. You will sign custody receipts for all equipment issued to your work center. You will keep records of tools issued, keep regular inventories, and submit requests for replacement of damaged or worn tools. You will ensure that all work center spaces are free of fire hazards. To prevent accidents, you will post operating and safety instructions on all portable and stationary machinery, enforce all safety rules, and assign only qualified personnel to operate the machinery. You will ensure that the signature of the person in charge of a job is entered in the block provided on the work request. You will add your own signature to indicate that you inspected the work and found it satisfactory. You will inform the division duty repair petty officer at the end of the working day of all urgent work that must be completed during the night.

PLANNING THE WORK.—The work center supervisor, with the assistance of the shop's leading petty officers, must plan each phase of each job assigned to the shop. Planning must include the lead jobs, the assist jobs from other repair work centers, the routine upkeep and maintenance, and nonproductive work, such as working parties. Lack of good planning will usually result in confusion, delay, and sometimes failure to meet the commitments of the work center. The supervisor must plan for the coordination of the various steps in the work. This involves consideration of available manpower, equipment, materials, and the work load of the other repair work centers.

Planning does not stop in the work center. The repair officer must know how many productive man-hours are to be available for repair work during a specific availability. Such knowledge enables the repair officer to determine how much work can be accepted during that period of time. This is where estimating comes into the picture. The work center supervisor must have the ability to give an accurate estimate of the time each job will consume. To do this, he will rely heavily on his past experiences and the experiences of other leading petty officers. Additionally, the work center supervisor must estimate the nonproductive man-hours caused by the work center's obligations to provide for working parties, mess cooks, special liberty, and so forth.

In planning the work, the capabilities of the personnel must be considered. An inexperienced person assigned to a difficult job will require an experienced person to be on hand to give direct supervision at all times. This is a good training opportunity when the work load of the work center is light. However, when the work load is heavy, the inexperienced person should be assigned to a job requiring skills more in line with his ability.

Another question to be answered in planning is the number of personnel required to accomplish the job. Having too many personnel work on the same piece of equipment is sometimes worse than not having enough. Each step of a job must be analyzed before the required number of personnel are assigned.

Other factors to be considered are the kind, sources, and quantity of materials needed to accomplish the repairs. What kind of materials are needed? How much is needed? Where are the materials obtainable? How much time will be given since occasionally the materials called for in the blueprint are no longer available? Time must be allowed for the research of suitable substitutes. All these factors must be considered by the supervisor of the optical shop.

Estimating the amount of material required to complete a job will be your responsibility. You must be able to estimate with accuracy the amount and kind of materials required by your work center. If you don't, you will either be caught short without the items you need, or you will find your work center cluttered with items you do not need. A high inventory level of slow moving materials ties up division funds that might be used to better advantage. Remember that running a work center is like running a business; you must operate within a budget. You can eliminate much of the guesswork in estimating if you use records of materials expended during the previous quarter. Include in the estimates the amount of material required for any special work you know is to be done during the period for which you are estimating. Plan and place work center orders for materials in advance with the supply officer through your division officer or department head. Do not bypass any of the normal supply channels of authority.

Inventory levels for most consumable items and repair parts are maintained by the supply department. Aboard repair ships or tenders, the OM1 or OMC assists the supply officer in maintaining the inventory on optical parts. Usually a high limit is kept on hand. Before the low limit is reached, the OM1 or OMC will request material needed to replenish the stock and maintain the high limit supply. When ordering, they must take into consideration the rate of use, the balance on hand, and the expected delays in shipment and delivery. Information concerning the procurement, custody, and inventory of repair parts and other supplies is covered in *Military Requirements for Petty Officer Third Class*, *Military Requirements for Petty Officer Second Class*, *Military Requirements for Petty Officer First Class* and *Military Requirements for Chief Petty Officer*.

In planning a job, the OM1 or OMC in charge of the work center should first perform the job step by step mentally. This procedure will help prevent the unintentional omission of some important step of the job. Once this is done, consideration should be given to each step to make sure that all requirements are taken into account.

Next the sequence of the operations must be determined. In some jobs, the more time-consuming operations may be performed first so that the largest part of the job is completed first. In other jobs, the less time-consuming operations may have to be done before any other operation can be performed.

Once the planning of the work has been done, follow the plans carefully. Make the plans flexible enough to meet any unforeseen circumstances and to allow for emergency repairs. If a change in plans is indicated, you as the supervisor must reevaluate the whole plan and make the necessary changes. Careful planning and follow-up of these plans will enable you to run your work center with the utmost efficiency and productivity.

LAYING OUT AND ASSIGNING WORK.—A Navy optical shop is primarily concerned with repair work. The assignment of work changes constantly according to the amount and type of work being done in the work center. When the work load is light, the less experienced personnel may be assigned to a complicated job under the supervision of an experienced petty officer. When the work load is heavy, the most experienced personnel are assigned to more complicated jobs and to urgent jobs. At times, reassignment of work is made to prevent delays, to accomplish added new work, or to expedite emergency jobs.

INFORMATION ON INCOMING JOBS.—Work requests generally are received by the work center several days in advance of the work. The work center supervisor should start his planning as soon as possible to gain an advantage of time. Much of the planning may be done before the work is delivered to the work center so that all necessary repair parts will be on hand when needed.

PRIORITY OF JOBS.—In planning and scheduling work in the work center, you must give careful consideration to the priority of each work request. Priorities are generally classified as urgent, routine, or deferred.

Deferred jobs do not present much of a problem; they are usually accomplished when the work load of the work center is light and few jobs of a higher priority are scheduled. Incidentally, these jobs are approved with the understanding that they will be accomplished when the time, personnel, and equipment are available.

The majority of work requests have routine priority assigned to them. Routine jobs make up the normal work load of the work center. They must be carefully planned and scheduled so that the daily organization and production can be maintained at a high standard.

Urgent priority jobs require immediate planning and scheduling. Jobs of lower priority must often be set aside so that urgent jobs may be accomplished. At times, personnel may be assigned to a night shift to complete these jobs on time.

DETERMINATION OF REQUIRED REPAIRS.—As soon as a job is delivered to the work center, the first thing you must do is to determine what kind of repairs are required. This is where your years of practical experience and up-to-date knowledge on different types of repair procedures are invaluable. During the planning stage, check with other leading petty officers in the work center for ideas on how best to accomplish the necessary repairs. Perhaps some of them have done the same job before. You may then assign some of the planning work to one of them.

After the necessary repairs have been determined, you must ascertain that the repair parts or materials are available. If they are not available on board, they must be requisitioned through the supply department. The activity requesting the repairs may even have the necessary repair parts on hand. If so, they may be used by the repair activity and then replaced when available. Frequently the repair parts must be manufactured, or temporary repairs must be made to the old parts. Matters of this nature must be cleared up before the job is laid out and assigned to less experienced personnel in the work center.

ESTIMATING TIME FOR A JOB.—Estimating time for the completion of a job requires considerable thought and foresight. Upon your estimate may depend the success or failure of a ship to meet its operational commitments. Failure to complete a job in the allotted time can result in considerable unnecessary expense and loss of valuable time. Each estimate that you make must be realistic, accurate, and dependable. An estimate, in a sense, is a guess, but it should be an intelligent guess based on experience and the proper use of records.

For most of the routine jobs that come into the work center, the work center supervisor gives a quick estimate of the probable time of completion. Generally, completion of routine jobs within a set time is not a necessity; however, repairs must be completed before the end of the availability period and in sufficient time for the ship's force to install the repaired equipment.

The estimation of time required to complete jobs of an urgent nature (priority) must be given considerable thought. For example, a last minute job may come up near the end of the repair period; or a ship in port for only a day or two may need an urgent repair job. The time required to make such repairs is an important consideration. In jobs such as these, the time estimate must be extremely accurate to avoid the waste that will result from starting a repair job that cannot be completed. Frequently, the final decision will be made by you, the OM1 or OMC in charge of the optical shop. Being experienced in repair work, you know the current work load; you also know the personnel and the equipment available in the work center. You will be expected to give an accurate estimate of the time required to complete almost any repair job.

TEARDOWN TIME.—In any repair job, the instrument to be repaired is disassembled only as much as is necessary to make the repairs without damage to other parts of the equipment. The teardown time is the time required to disassemble a piece of equipment after it has been delivered to the work center. Teardown time is then doubled to allow sufficient time for reassembly. If any dismantling is necessary before delivery to the work center, an estimate of this time will be made by either the ship's force (customer ship) or by other repair department personnel.

MISCELLANEOUS TIME ALLOWANCE.—One final factor to consider when estimating time is often overlooked. This factor is the allowance for miscellaneous time. Allowance must be made for delays caused by physical or mental fatigue, for personal time, such as head calls, rest breaks, meals, and for other times that do not fall into a specific category.

After you have made an estimate of time required to complete a job, make a record of it so you may refer to it later. Once the job has been completed, compare the actual time expended against your estimate. By doing this, you will soon be able to improve your man-hour estimating skill.

WORK LOAD CONSIDERATIONS.—The work load of the work center must be carefully considered before a new job is approved for completion within a certain time.

After a decision has been made as to what repairs or replacements are necessary, the petty officer in charge will be able to determine what tools and personnel should be used for the job. His next step will be to check on the present and scheduled work. If an urgent priority has been given to a job, then the work being done by the repairman will be set aside until the proposed job has been completed. If the new job does not have an urgent priority, it will be dovetailed, according to its priority, into the schedule of work being done.

You must also decide the number of hours per day personnel will be assigned to work on a job. If the job is to be routine, normal working hours should be considered. If the job has an urgent priority, three shifts may be assigned to the job, and personnel will be required to work 24 hours a day.

In brief, the selection and assignment of personnel will depend upon the magnitude and complexity of the new job under consideration as well as its assigned priority. In turn, job priorities depend upon the work load of the shop, unless the new job is given an urgent priority.

REQUIRED PARTS AND MATERIAL.—After a decision is made as to the extent and nature of repairs required, a check must be made to see if the required material and parts are available on board ship. The material must be available before you attempt to estimate the time of a repair job. Items that may be required, such as gaskets, studs, bearings, and shaft keys, must not be overlooked.

Some materials can be kept in the optical shop in sufficient quantities to avoid delay caused by frequent trips to the issue room. For some items a 30-day supply is adequate; for others, a 90-day supply may be necessary.

Usually, as an OM1 or OMC, you will know from experience where each item is located in the work center; you will keep this locator file in your head. You should also attach a list of the contents to each drawer or cabinet so the rest of the personnel in the work center will also know where things are stowed. Remember how important good housekeeping is in getting the work out. Have a place for everything and keep everything in its place. Be sure your storage facilities have adequate provision for securing for sea.

Naval ships carry an allowance of repair parts for machinery and equipment on board ship. A check of the ship's COSAL will show if a certain part is being carried on board. However, in some instances this check is overlooked. You do not need to manufacture an item such as a gear if the ship carries gears for the instrument that requires repair. By locating available repair parts, you will save a great deal of time in doing the repair jobs and your estimate can be made accordingly.

CONSIDERATION OF THINGS THAT MAY GO WRONG.—Experience is an excellent teacher of things that may go wrong when doing a repair job. As an experienced supervisor, you can avoid many of the difficulties that may arise in performing repair work. When planning and estimating a repair job, you should carefully consider all possible difficulties that may arise and allow extra time for them. Adequate blueprints or other drawings should be on hand. If you have sufficient information before starting the job and a clear view as to the total amount of repair work required, avoiding mistakes and delays is easier.

The repair job itself may cause a certain amount of breakage or damage. In such instances, the supervisor who has estimated 30 minutes for removal of the parts may find that it takes 4 hours.

Failure to ensure that a person fully understands the details of a job may result in the work being done improperly. For the supervisor to have all the details is useless if the person doing the work is not informed or does not understand the instructions. The supervisor must make sure that every detailed instruction is thoroughly understood by the personnel doing the work. Some persons will say they understand instructions when they actually don't because they are afraid of appearing ignorant. Remember, when the job, or part of it, has to be done over, the original estimated time of completion will no longer be valid.

When the unit to be repaired consists of a number of assembled parts, some of the parts may be rusted or frozen so that removing them is extremely difficult. During the original inspection of the items in need of repairs, watch for any indication that the unit may be difficult to disassemble; then allow extra time to cover this phase of the repair job.

If an item fails to pass any required tests after repair, additional work will be necessary. The required tests, and the possibility of additional work associated with tests, must be considered when making repair job time estimates.

The time required to deliver an instrument to the work center should not be included in the estimated time to do a repair job. If boat and crane service are involved in a proposed job, the requesting activity should inform the work center supervisor. When requested to estimate time of transportation, the supervisor should make separate estimates for the time needed to complete work on the instrument and the time needed for delivery. Boat and crane service may be unpredictable at times; therefore, you should check with the officer of the deck and the crane operator before making any estimate of this kind.

When determining personnel requirements for a job, keep in mind the possible inspections, drills, and working parties that may occur that will delay the repair job. If the assigned personnel cannot be excused from these activities, add extra time for the completion of the repair job.

The factors discussed above do not cover all things that may go wrong on a repair job. They indicate the types of things which you will have to consider when estimating the time required to do a repair job.

SUPERVISING REPAIR WORK.—One of the most important duties of a First Class or Chief Opticalman is that of supervising the repair work in the optical shop. As a supervisor, you must instruct work center personnel concerning the different repair jobs which have to be done. You must also check on the progress of the work and provide additional advice or instructions when necessary. You should always check the completed job to see that it has been done properly and according to existing instructions.

After you have obtained complete information on a new job and have decided what repairs or replacements are necessary, decide who is to do the job. In making this decision, consider the experience of your people and the skills they have in operating the various machine tools.

CHECKING THE PROGRESS OF WORK.— The assignment of a job is the first step in processing a job through the work center. You, the supervisor of an optical shop, must know your personnel. You should have a fairly good idea of each person's skill and ability for accomplishing the repair work.

Being a supervisor, you should frequently inspect the progress of the various jobs in the work center. By doing this, you can see which jobs and personnel require additional attention.

When checking on the progress of work, be sure that personnel are observing proper safety precautions in regard to themselves and the machines they are operating. Make sure that all items coming into the work center are properly tagged. Instruct personnel in the work center to replace any tags that have been removed. Tagging will eliminate the mix-up of items as well as a lot of unnecessary confusion and lost time.

Always check to see that personnel understand your instructions properly or are doing the work correctly as indicated by a blueprint or drawing. If necessary, provide additional instructions to give a better understanding of the job or to improve workmanship. By frequently talking to your personnel and by answering their questions, you can prevent costly mistakes. Supervisors who show interest and confidence in their personnel and their work will find that their personnel have confidence in them as good work center supervisors.

Since complications may develop on some repair jobs, additional planning and revised repair procedures may be required. You should observe the progress of the various jobs and determine which jobs are ahead or behind schedule. You will then be able to change the schedules as necessary to prevent "bottlenecks" and keep the most important jobs moving.

CHECKING COMPLETED JOBS.—When a job has been completed in the work center, the supervisor should inspect and approve the job. Inspection is necessary to ensure that the repair job or the manufactured replacement part will be satisfactory both to the repair activity and to the ship's force that is going to use and depend upon it. Inspection of parts may be accomplished either visually, by means of measuring instruments, or, when applicable, by means of tests performed to check the condition of repaired equipment.

As you advance in rating to OM1 and OMC, you will be required to assume more responsibility for the paperwork so necessary in a well-organized work center. In fact, to avoid bogging down completely in the mass of details, you will probably delegate some of these duties to an assistant in the work center. Keeping records up to date will enable you to keep a close check on each job, each person, and each piece of equipment under your supervision.

All completed work requests should contain the man-hours expended, the material used, and a full description of the work accomplished. All necessary records and paperwork should be correct and up to date. When the job has been completed, the interested parties should be notified. Completed jobs should not be allowed to accumulate, as some of the items may become mixed up, damaged, or lost.

Before releasing a completed item, be sure that (1) the correct work request is signed by a representative of the requesting activity, (2) the identification on the item and on the work request coincide, and (3) all manufacturers' technical manuals and blueprints furnished with the work request are returned.

General Housekeeping

Generally, you can give a work center one good look and tell whether it is efficient and well run. Just make a quick survey for cleanliness, neat tool and stock stowage, and the condition of equipment. If such a survey reveals a high quality of housekeeping, you can usually assume that the work center is well organized and really turns out the work.

Material and supplies—screws, bolts, and gasket material—must be stored in a convenient, secure, and orderly place. Cabinets, shelves, bins, and racks should be arranged in the work center to give the greatest possible amount of free working space.

If the work center space permits and sufficient tools are available, individual personnel should have their own stowage drawers and toolboxes in which they can keep their own tools. (People don't like to use drill bits that someone else has nicked or burned. They like to have their own hammers, chisels, and screwdrivers.) Besides speeding up production, this method of stowage will provide better care and cleanliness of hand tools.

If space permits, one corner of the work center may be blocked off for use as a toolroom. In this room can be kept such tools as portable power drills, grinders, grinding wheels, large dividers, pipe wrenches, C-clamps, large drill bits, special files, dies, tap wrenches, and diestocks. A striker should be made responsible for keeping the tools in order and issuing them as required. This toolroom job should be rotated among the strikers to give each man an opportunity to learn the names and uses of all the tools.

Proper tool storage is important in the optical shop. Lockers, racks, drawers, cabinets, and boxes are used for stowing tools. The place selected depends largely on the use of the tool, the frequency of its use, its size and shape, and its value.

Drill bits, micrometers, torch tips, combination squares, gages, and the like, must be stowed so that they are protected from contact with other tools. Edged tools and pointed tools, such as scribers, dividers, and compasses, require special stowage to prevent damage to cutting edges and sharpened points. Particularly valuable and hard-to-get tools should be kept locked in special lockers, drawers, cabinets, or toolboxes.

These tools include portable power tools, gages, micrometers, special pliers, wrenches, files, and drills.

Tools frequently used outside the shop should be made up into kits and stowed in convenient toolboxes. Tools used in your work center may be marked with a distinctive color for identification. If so marked, they are not easily mixed with tools that belong to other shops.

Good housekeeping requires that bench tops and power equipment be kept clear of unnecessary tools and material, scrap stock, filings, dirt, and excess oil and grease.

PRODUCTION CONTROL

As an OM1 or OMC, you may become a shop supervisor. It will then be your responsibility to see that all work is done properly and on time. To accomplish this, you will function in three main ways:

1. You will plan and organize the work so that maximum production is accomplished with a minimum of effort and confusion.
2. You will delegate, as much as possible, the responsibility and authority for completing the work, while keeping in mind that the quality of the final product is your responsibility.
3. You will continuously oversee the work while it is in progress, ensuring that it is being done in accordance with prescribed instructions. You will also make all necessary checks before the work leaves the shop.

Remember the quality of the finished product reflects the skills of the whole shop and, in final analysis, your own skill as a supervisor.

CHAPTER 2

OPTICAL ALIGNMENT

Since an increasing number of new equipment is being installed on board naval ships and because newer optical instruments require alignment, you (as a senior Opticalman) will have to adapt your alignment equipment to these requirements. You may also have to develop new procedures to accomplish effective alignment of optical instruments with the equipment you have available. This chapter is designed to help you carry out your alignment tasks.

The processes of optical alignment and collimation fall into the category of repair work known as calibration. Calibration is a comparison of a test instrument to a known or fixed standard. The accuracy of your alignment will be restricted, to a point, by the accuracy of your standard, whether it is an alignment telescope or an alignment collimator. Since your equipment serves as a reference device, it should be calibrated periodically to ensure its accuracy. According to the Metrology Requirements List, NAVAIR 17-35 MTL-1, optical alignment equipment should be calibrated at least once every 12 months.

In this chapter you will be introduced to the various equipment used in optical tooling. Once you understand the basics of this equipment and how the equipment is used, you will have little trouble setting it up and making alignments within close tolerances.

OPTICAL TOOLING

Optical measurement instruments have long been used by astronomers, surveyors, and photographers. However, until a few decades ago, optical instruments, with the exception of the optical aids on linear measurement devices, found little use in production and assembly shops. Today optical measuring instruments (referred to as optical tooling) are common and necessary tools in assembly plants and at installation sites.

The aviation field began using optical tools at the end of World War II. Optical instruments were used to hold production tolerances that were normally considered impossible but necessary for the higher speed of aircraft. More recently, optics have moved into nuclear energy, missile manufacturing and launching, and now into shipbuilding. They are the most economical and accurate means of measuring sizes beyond the mechanical limits of surface plates, height gages, mechanical squares, and so forth.

Optical tooling is a system that uses precision optical alignment instruments to establish and maintain lines of sight, or beams of light, as reference lines. Instead of measuring between two points common to a single instrument, as is done in linear measurements, settings and displacement readings are taken directly from the line of sight.

Because of their sizes and high speed, modern machineries require very accurate alignment. They are designed and built around optical lines of sight and involve tolerances that are measured in thousandths of an inch to reduce mechanical errors. Optical tooling allows you to establish an optical reference line parallel to one axis of the object being worked and then to establish optical planes at right angles to the basic reference line. These references can be quickly and precisely set with errors in positioning and alignment held to less than 0.001 inch. Optical lines of sight can be established in all three planes; thus, you can establish a coordinate system of measurements that establishes definite locations in either *horizontal* or *vertical planes*, with accuracies of 1 to 2 seconds and *linear* measurements of 0.002 to 0.006 inches in 100 feet.

Once established, the line of sight can be moved sideways or up or down, either parallel to the original position or swept with horizontal and vertical planes passing through it.

BASIC CONCEPTS

The basic concept of optical tooling is that *two points establish a line*. Many lines pass through each point (up, down, sideways, and so forth).

However, one, and only one, line passes through both points. A third point may lay on the line defined by the first two points. If it does, the point is said to be collinear or, more commonly, is expressed as, "the third point lines-up" or "is in line." If the third point does not fall on the line, it is noncollinear or "out-of-line."

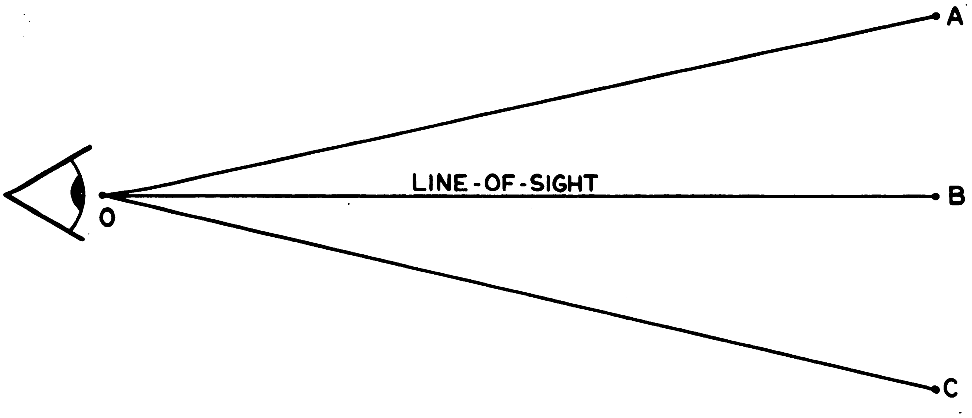
Optical tooling instruments require only one point external to the lens to establish a line. The center of the lens of the instrument is always the primary reference point. When we look at a distant object, a line of sight is established between that object and the center of our eye. Almost without exception, this line of sight is along the principal axis of the eye. The principal axis is defined by a line that passes through the center of the lens and is directed in the direction in which the lens is "pointed" or "aimed." This basic concept is illustrated in figure 2-1.

The eye illustrated in figure 2-1 is "looking" at point *B*. The line defined by points *O* and *B* is the principal axis of the eye and, therefore, is the line of sight. Two other lines between the eye and objects are shown in figure 2-1. These are lines *OA* and *OC*. These lines are not in the direction in which the eye is looking and, hence, do not constitute lines of sight. Lines *OA* and *OC* may have the same significance as lines *OB* in geometry; but as far as the optical instrument (the eye) is concerned, they are not as important as line *OB*.

A line of sight used in optical tooling has one further requirement. The line of sight must be directed in the direction of the measurement. To establish if a row of marchers in a parade form a line, you must direct your line of sight along the row of marchers. For example, in figure 2-2, only observer B can determine the alignment of the row of marchers shown, because B is the only observer whose line of sight is directed along the row of marchers.

OBJECTIVE OF OPTICAL TOOLING

The objective of optical tooling is to establish a reference line for all measurements. You establish this line by placing the optical measuring instrument at some convenient location and



148.376

Figure 2-1.—Line of sight concept.

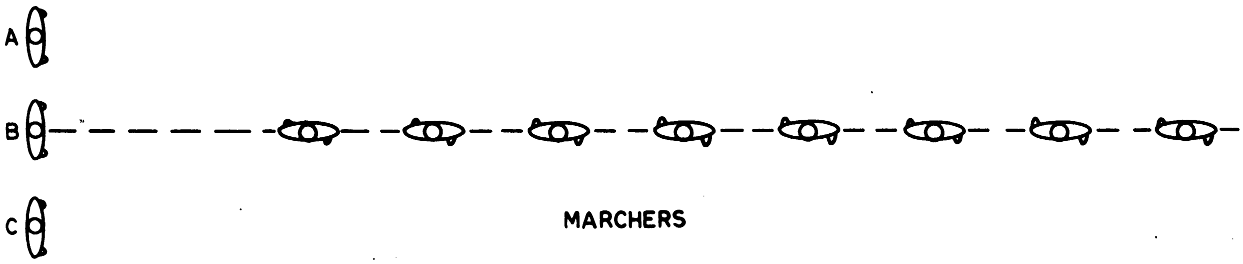


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Figure 2-2.—Alignment of the line of sight.

pointing it at a second reference point or in a given direction. The most common method used to establish the line of sight is to ensure that the line is horizontal and is directed in some general direction; that is, along the wall of a building or towards the North Pole.

Once the first line of sight is established, the remaining reference lines are generated from it. These are normally vertical lines passing through the primary point of the first line. The third reference line is a second horizontal line perpendicular to the first line, which also passes through the primary point. These lines are illustrated in figure 2-3. The primary point is the center of the optical measuring instrument.

You can exactly locate a given point on the work by measuring its coordinates along these reference lines. Also surfaces can be aligned parallel, perpendicular, or inclined to any of the planes defined by these reference lines.

GEOMETRIC CONCEPTS OF OPTICAL TOOLING

The basic objectives of optical tooling are to establish reference points, lines, and planes. Precision measurements can be made to these references in the production or assembly of a large device. The first reference is the *master point*, which serves as the starting point. Although this point need not be precisely known relative to the earth, it must be stable; that is, it must remain fixed during the period of use.

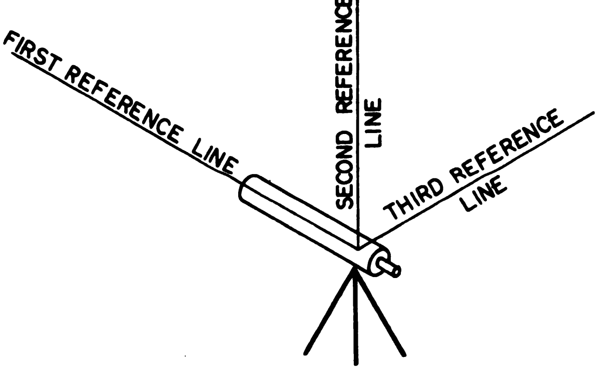

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Figure 2-3.—Reference lines.

There are two optical tooling techniques. The establishment of the master point is different for each technique. One technique is the *attached* method. In this method the references are attatched to the work. The other technique is the *detached* method. In the detached method the references are established on stands, tooling bars, and so forth which are free of the work. While the detached method provides the greatest flexibility and ease of application, the attached method tends to be more accurate.

In the attached method, the master point is established by placing a sphere in such a position that its center is located at a known or convenient point. The sphere may be either a target holder or an instrument (alignment telescope) holder. The use of a sphere allows for rotation about the reference point without lateral movement of the point.

These spheres are not complete spheres. They consist of spheres that have been sliced and drilled as shown in figure 2-4. The sphere size is standardized in outside diameter, internal bore, and width.

Spheres are placed in cups that have the same radius as the sphere. The cups are also standardized so that they accept the sphere and locate the center of the sphere a fixed distance above the base of the cup.

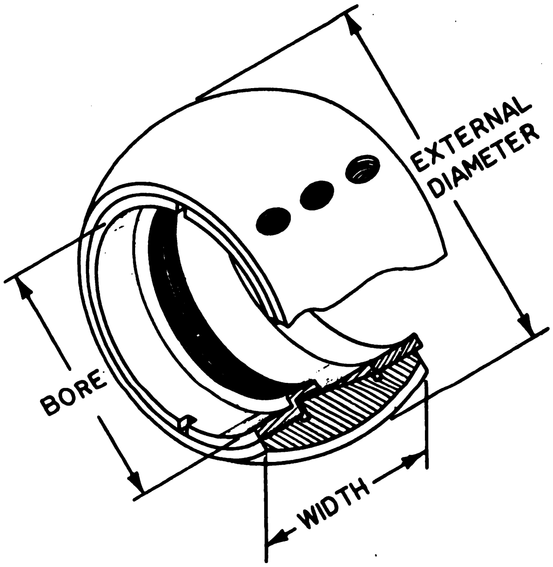

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Figure 2-4.—Spherical mount.

In the attached method, a second reference is needed for the construction of the reference line. The line between the master point and this second reference point defines the *master line*. Usually this line is horizontal; however, it need not be. Figure 2-5 shows the establishment of the master line using the attached method.

For the detached method, the master point is the center of an instrument located on a stand some distance from the work. The master point and master line are usually established before the work is moved into the production or assembly area. A horizontal line passing through this point in a known or convenient direction becomes the master line. In this case, the secondary point may be established by the master line.

The second major reference line for either method is established by the line that passes through the master point perpendicular to the master line and is vertical (detached) or parallel to the plane of the work (attached). The third major reference line is the line that passes through the master point and is perpendicular to both the master line and the secondary reference line. These three mutually perpendicular lines (each is perpendicular to the others) form the axes of the coordinate system that will be used as the reference for all measurements. The detached coordinate system is shown in figure 2-6.

ALIGNMENT TELESCOPES

The alignment telescope is the most widely used instrument in optical tooling. It is the instrument used to establish the master reference lines of sight from which measurements can be taken. The British were the first makers and users of alignment telescopes. They replaced conventional alignment gages and gaging systems with the alignment telescope during World War II when they were building their four-engine bombers.

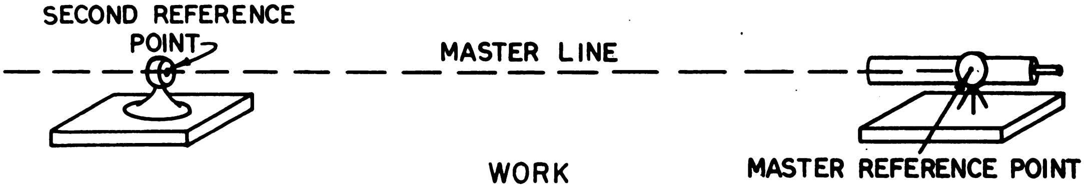

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Figure 2-5.—Master line—attached method.

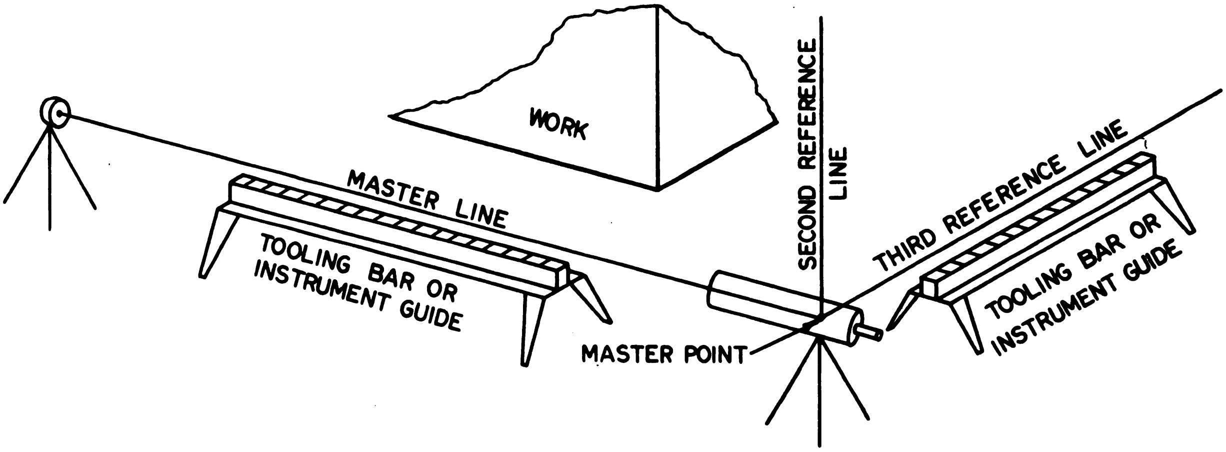

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Figure 2-6.—Coordinate system—detached method.

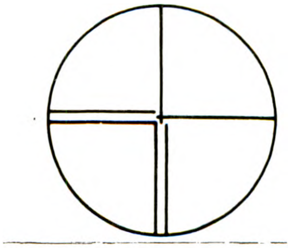
An alignment telescope (fig. 2-7) is used to establish straight lines for measurement reference. This reference is the line of sight of the telescope.

In the following paragraphs we will discuss the model 71 2022 alignment telescope and the model 71 2062 line of sight telescope produced by Keuffel and Esser Company.

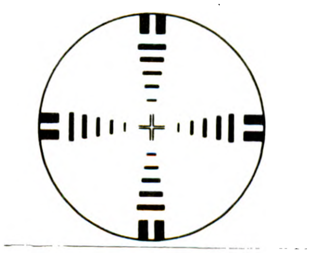
71 2022 ALIGNMENT TELESCOPE

The barrel of the 71 2022 alignment telescope consists of a heavy, through-hardened, stabilized tool-steel tube. The objective end is a cylinder approximately 9 inches long with a hard, chrome surface ground to a 2.2498 + 0.0000/ − 0.0003 inch diameter (Aircraft Industries Association standard diameter). The rear section contains horizontal and vertical optical micrometers, the focusing knob, and the eyepiece. The line of sight is adjusted so that it coincides with the axis of the cylinder.

The telescope is erecting and can be focused from zero to infinity. Magnification varies automatically from 4X at zero focus to 46X at infinity focus. It has an effective aperture of 42 mm. Resolving power is 3.4 seconds of arc (according to the Bureau of Standards test procedure). The image is especially bright and clear with excellent definition. Coated optics are used throughout. An all-purpose, double glass reticle (figure 2-8, A) gives a cross pattern with single lines top and right, and paired lines bottom and left. An autoreflection target (fig. 2-8, B) and an autocollimation illumination unit are built in.



A. Reticle Pattern



B. Auto-Reflection Target Pattern

148.383X

Figure 2-8.—Reticle and autoreflection target

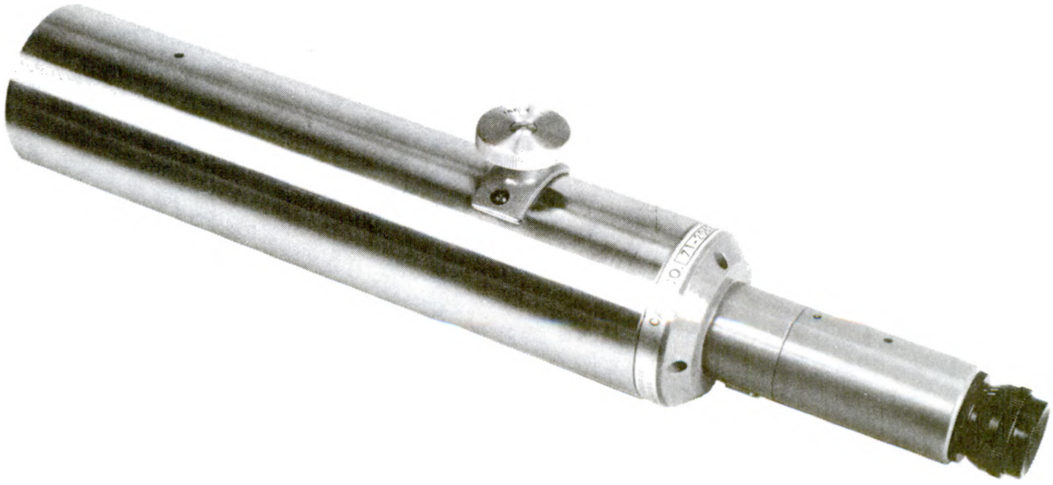


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Figure 2-7.—Alignment telescope.

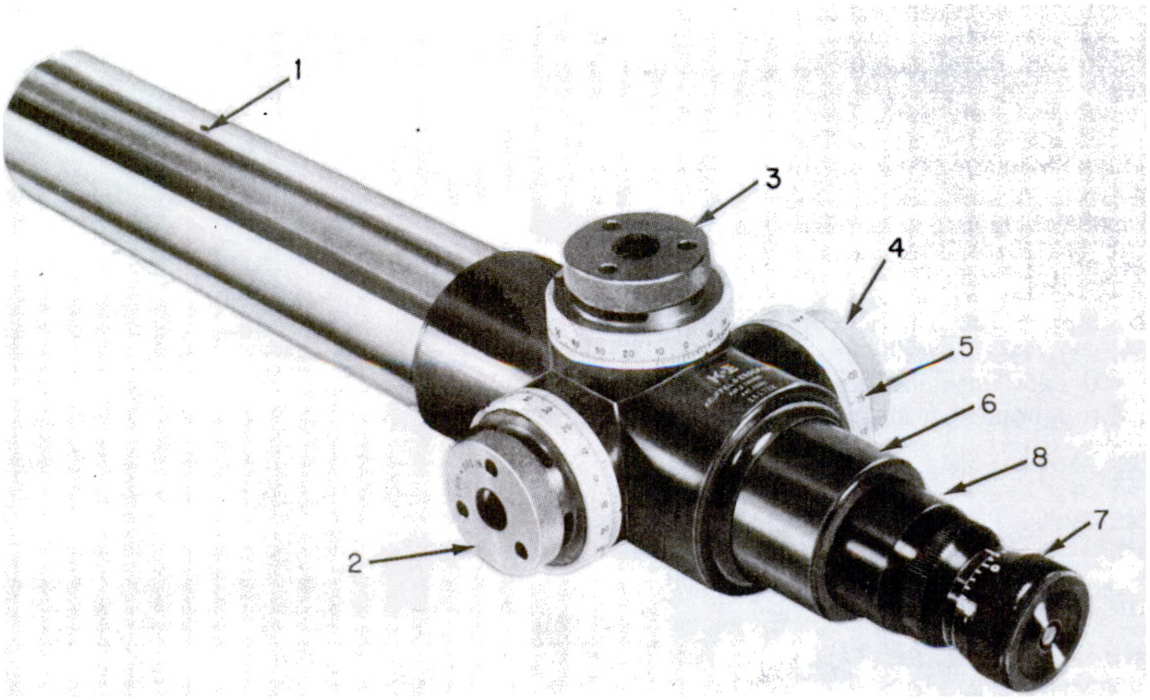
The main operating features of the alignment telescope are shown in figure 2-9. Their functions are described in table 2-1.

71 2062 LINE OF SIGHT TELESCOPE

Like the alignment telescope, the line of sight telescope is used to establish a precise reference line of sight from which measurements can be taken. The barrel of the 71 2062 line of sight telescope consists of a heavy, through-hardened, stabilized steel tube with a hard, chrome surface that is ground to 2.2498 inches +0.0000/−0.0003 inch (Aircraft Industries Association standard diameter.) The telescope focusing knob is mounted on the barrel. The eyepiece is an erecting, achromatic eyepiece with a removable blank that permits installation of an accessory autocollimation conversion unit.

The telescope is especially bright, with excellent definition. Magnification varies automatically from 23X at 7 inches to 35X at infinity. The effective aperture is 38 mm. Resolving power is 3.5 seconds of arc (according to the Bureau of Standards test procedure). Fully coated optics are used throughout. An all-purpose, double glass reticle gives a cross pattern with single lines top and right and paired lines bottom and left. The instrument is furnished with a built-in autoreflection target and an autocollimation illumination unit.

The main operating features of the line of sight telescope and their functions are indicated in figure 2-10 and described in table 2-2.



1. **Pilot hole**
2. **Knob for optical micrometer for horizontal measurement**
3. **Knob for optical micrometer for vertical measurement**
4. **Focusing knob**
5. **Cover for reticle**
6. **Eyepiece**
7. **Eyepiece focusing knob (diopter control)**
8. **Distance scale (reads in feet)**

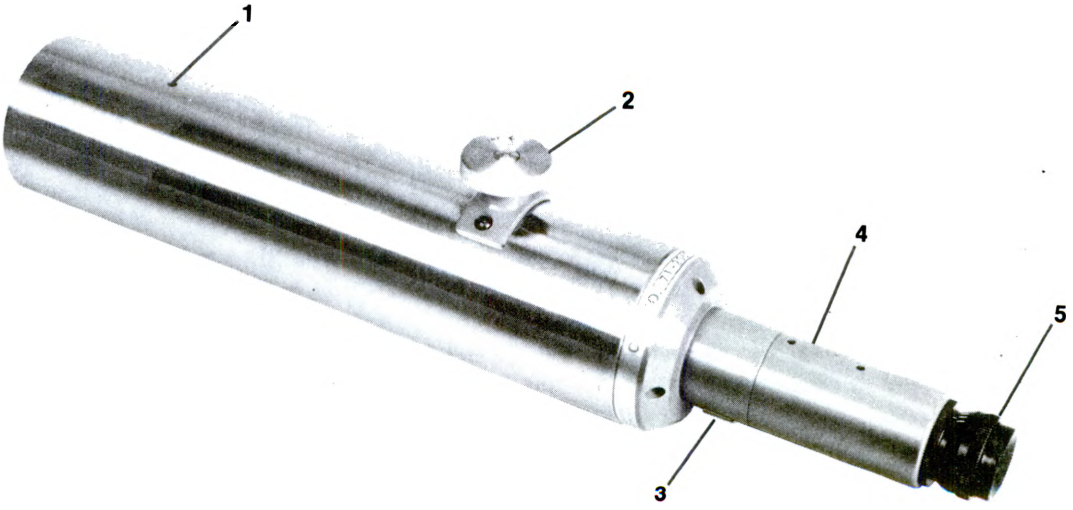
148.384X

Figure 2-9.—An alignment telescope.

Table 2-1.—Alignment Telescope, Operating Controls

Nomenclature	Function
Pilot hole	Serves as locating hole for accessory cross level.
Horizontal optical micrometer	Used to measure horizontal displacements from line of sight.
Vertical optical micrometer	Used to measure vertical displacements from line of sight.
Focusing knob	Focuses instrument on target.
Distance scale	When instrument is focused on target, indicates distance to target.
Cover for reticle adjusting screws	Protects reticle adjusting screws during use of instrument.
Eyepiece focusing knob	Focuses reticle cross lines.

148.385X



1. Pilot hole
2. Focusing knob
3. Coverplate for autocollimation illumination unit
4. Cover for reticle adjusting screws
5. Eyepiece focusing knob

148.386X

Figure 2-10.—71 2062 Line of sight telescope.

Table 2-2.—Line of Sight Telescope, Operating Controls

Nomenclature	Function
Pilot hole	Serves as locating hole for accessory cross level.
Focusing knob	Focuses instrument on target.
Cover plate for Auto-Collimation Illumination Unit.	Access to illumination unit receptacle.
Cover for reticle adjusting screws	Protects reticle adjusting screws during use of instrument.
Eyepiece focusing knob	Focuses reticle cross lines.

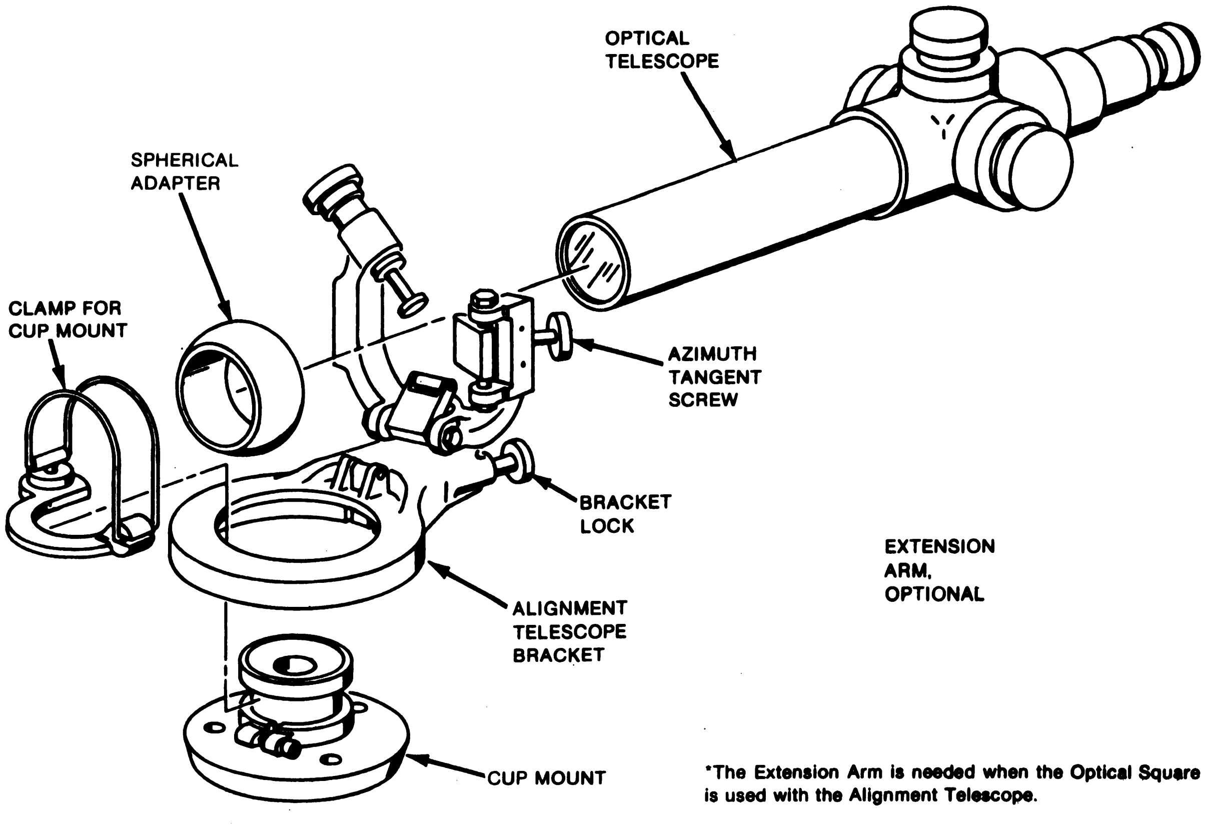
148.387X

BASIC INSTRUMENT CONCEPTS

Alignment telescopes and line of sight telescopes were designed for one specific application—optical tooling for the airframe industry. The original concept was that a person could establish a line in space by locating two spherical adapters, one at each end of the line. This was usually accomplished by a person placing each of the spherical adapters in a cup mount and measuring to the outside diameter of the sphere, thereby positioning the center of the sphere where required. Once the spheres were properly located, the base of each cup mount was pinned to the structure or tool, and the vertical adjusting screw of the cup mount was clamped and usually pinned; therefore, the cup mount became a permanent locator fastened directly to the tool itself.

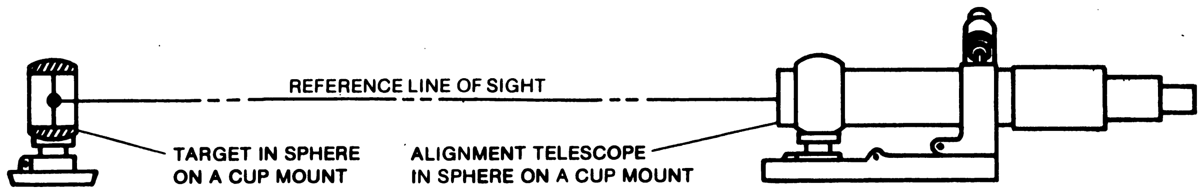
To establish the optical reference line with this arrangement, you must place a target in one of the spherical adapters and mount it on the cup mount at one end; then place an alignment telescope or line of sight telescope in the other spherical adapter and place it, along with a suitable bracket, on the cup mount at the other end (fig. 2-11 and 2-12). The bracket supports the rear end of the telescope, and its fine motion tangent screws aid in aiming the telescope. Then you must only aim the telescope at the target to establish an optical line of sight from the center of one sphere to the center of the other sphere. Intermediate targets indexed to part locators by permanently mounted special fixtures can then be aligned to the reference line of sight. At this point, the telescope and spherical adapters can be removed from the cup mounts, and the intermediate targets from their fixtures, and put away. At any future time, any set of targets, any two spherical adapters, and the telescope and target can be used to reestablish the reference line of sight and to check the location of the various part locators. The optical reference line was previously established by the use of tightly stretched wire instead of the reference line of sight.

The "optical tight wire" concept allowed the alignment telescope and the line of sight telescope to be designed specifically for the airframe industry and to be adapted for other applications. One of the first such applications was in the shipbuilding industry. Although telescopes had



148.388X

Figure 2-11.—Assembly of cup mount, spherical adapter, bracket, and alignment telescope.


REFERENCE LINE OF SIGHT
TARGET IN SPHERE ON A CUP MOUNT
ALIGNMENT TELESCOPE IN SPHERE ON A CUP MOUNT

148.389X

Figure 2-12.—Establishing a reference line of sight.

been used previously to align the bearings for the main drive shafts of vessels, the alignment telescope and the line of sight telescope offered many advantages over such jury-rigged telescopes. Unfortunately, the bracketry used in the airframe industry, specifically cup mounts and spherical adapters, have proved somewhat impractical for most applications outside the airframe industry; therefore, V-blocks of some sort are most commonly used instead.

A cone-type V-block consists of two or four cones on elevating screws. The cones are separately adjustable in height and can be locked in position by clamps. The telescope cylinder is held on the cones by springs. The two-screw-type V-block can be used with a cup mount, in place of a bracket, to aim the telescope. The four-screw-type V-block provides complete control of the telescope. The height of the cones is adjusted to control the aim of the telescope (fig. 2-13). Assume that screws *1* and *2* in figure 2-14 are the forward screws. The numbers in table 2-3 refer to the screws turned for the corresponding operation. All screws are turned equal amounts for each operation. The adjusting screw clamps should be snugged up to the point that there is a slight drag on the adjusting screws as they are turned. This minimizes any motion when the clamps are fully tightened after the adjustments have been completed.

The precision-ground barrel of the telescope was originally designed to be centered in a spherical adapter. When a V-block is used, the precision-ground barrel provides a self-proving feature to the adjustment or relationship of the line of sight to the outside barrel of the telescope. More importantly, the outside barrel of the telescope can be used to locate the optical center of the instrument. The telescope can be reversed in the V-block so that the line of sight can be extended in the opposite direction.

OPERATION OF TELESCOPES

To establish a reference line of sight (fig. 2-14) with the alignment telescope after it is mounted, proceed as follows:

1. Set the optical micrometers to zero (fig. 2-15, view A).

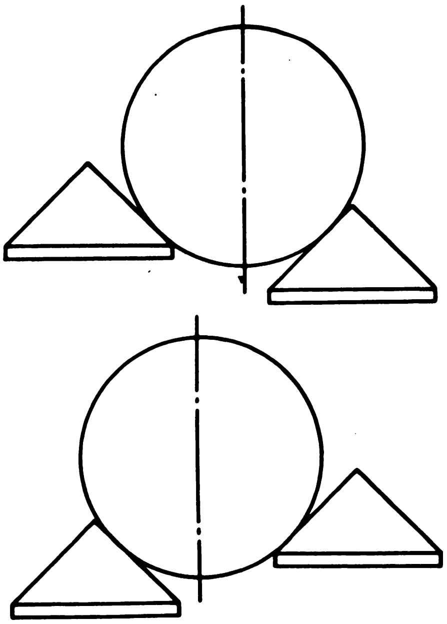


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Figure 2-13.—Use of cones to change aim left or right.

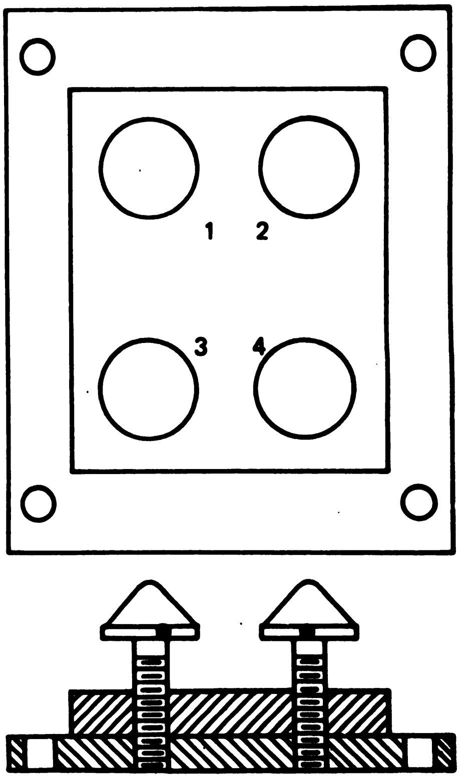

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Figure 2-14.—Schematic of cone type V-block.

Table 2-3.—Adjustment of the four-screw-type V-blade

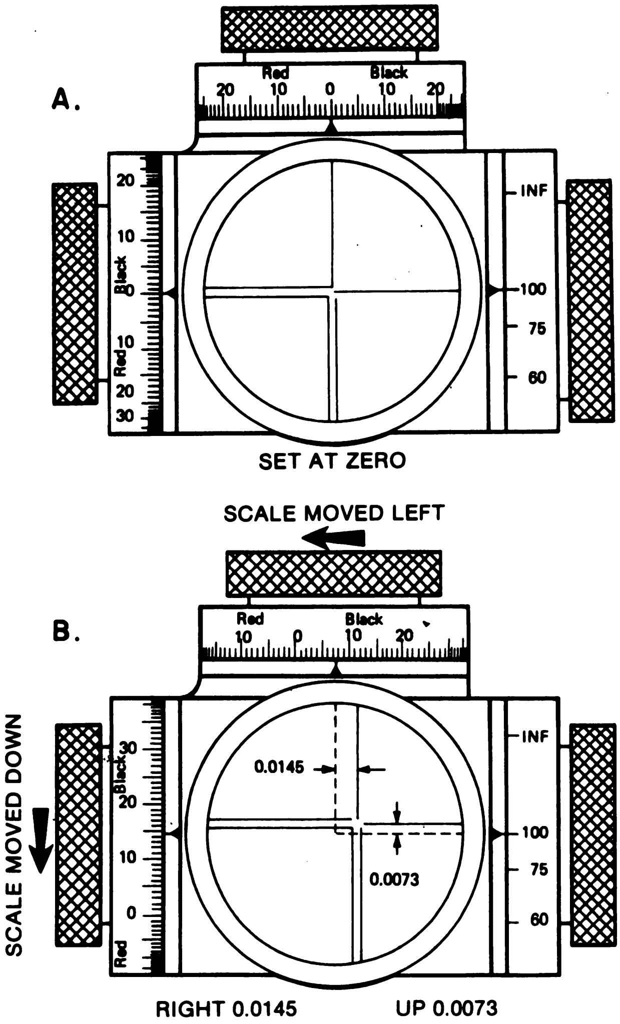
Operation	Screws Turned Clockwise	Screws Turned Counterclockwise
Raise	None	1, 2, 3, 4
Lower	1, 2, 3, 4	None
Move right	2, 4	1, 3
Move left	1, 3	2, 4
Aim up	3, 4	1, 2
Aim down	1, 2	3, 4
Aim right	2, 3	1, 4
Aim left	1, 4	2, 3

With the four-screw type V-block, measurement is made to the telescope cylinder itself, rather than to the spherical adapter.

148.391X

2. Turn the eyepiece focusing knob (fig. 2-15, view B) until the reticle crosslines appear sharp when the instrument is aimed at a well-illuminated white surface.

3. Note the resulting setting (the diopter setting) on the scale in front of the eyepiece



SET AT ZERO

RIGHT 0.0145 UP 0.0073

148.393X

Figure 2-15.—Operation of optical micrometers.

focusing knob for future use. This setting is often different for different observers and sometimes for different instruments, but it is the same for sights of different lengths.

4. Aim the instrument at the target, focus on the target using the focusing knob, and then refine the aim of the instrument at the target either by adjusting the tangent screws or by regulating the cones.

5. Measure the displacements from the line of sight. The alignment telescope has three control knobs (fig. 2-9). Viewed from the eyepiece end with the telescope in its normal position, the right-hand knob is the focusing knob; the left-hand knob is the horizontal micrometer knob, which moves the line of sight left and right; and the top knob is the vertical micrometer knob, which moves the line of sight up and down. Marks on a dial beside the focusing knob show the approximate position of the knob when the focus is at infinity or at various finite distances.

The extent of movement of the line of sight produced by the micrometer knobs is shown by graduated dials (fig. 2-15, B). The dials are graduated in units of 0.001 inch and are numbered in both directions from zero at the center to 0.050 inch. Black numbers are used in one direction, and red numbers in the other direction. When the dials are set at 0.000, the line of sight of the alignment telescope is on the axis of the cylindrical part of the telescope. When the horizontal micrometer knob (left) is turned clockwise, the face of the dial nearest the observer moves downward, the black numbers are adjacent to the index, and the line of sight moves to the right. Similarly, when the vertical micrometer knob is turned clockwise, the nearest face of the dial moves left, the black numbers are adjacent to the index, and the line of sight moves up.

Displacements of objects from the line of sight are measured with optical tooling scales. The lowest graduation of optical tooling scales is 0.001 inch. The optical micrometers of the alignment telescope read ±0.050 inch; therefore, when optical tooling scales are used, you may have to adjust the optical micrometers to bring the line of sight onto the nearest graduation of the optical tooling scale. The optical micrometer dial reading is then either added to or subtracted from (depending on the direction of displacement) the final optical tooling scale reading.

OTHER APPLICATIONS

In addition to establishing a reference line of sight, alignment telescopes and line of sight telescopes can be used to establish the following:

1. A plane perpendicular to a reference line at a given station
2. A level reference line and a plumb reference plane
3. A vertical plumb line

Establishing a Plane Perpendicular to a Reference Line

A perpendicular plane is established with either an optical square (fig. 2-16) or a double sphere optical square (fig. 2-17). Both optical squares provide one line of sight that passes straight through. By means of a pentaprism, both optical squares also provide a second line of sight that is turned 90° ±1 second of arc, from its entering direction. The apex of the 90° angle is at the center of the sphere. Adjustments about the sphere do not change the position of the intersection of the two lines.

When either optical square is mounted on the instrument, you can turn the 90° line in the direction needed by rotating the instrument and the optical square together. However, only the double sphere optical square can establish the 90° line through a full 360° rotation. The 90° line of the single sphere optical square is partly obstructed by the mount and bracket. When the double sphere optical square is mounted on its rear sphere, adjustment will move the intersection of the 90° lines; when it is mounted on the forward sphere, it will function as a single sphere optical square.

When you use an alignment telescope or line of sight telescope with an optical square to establish a perpendicular plane, the following procedure should be followed:

1. Mount the instrument with the attached optical square on a bracket. Either sphere of the double sphere optical square can be placed in the cup mount.
2. Cover the 90° opening of the optical square with the cap provided, and open the front window.

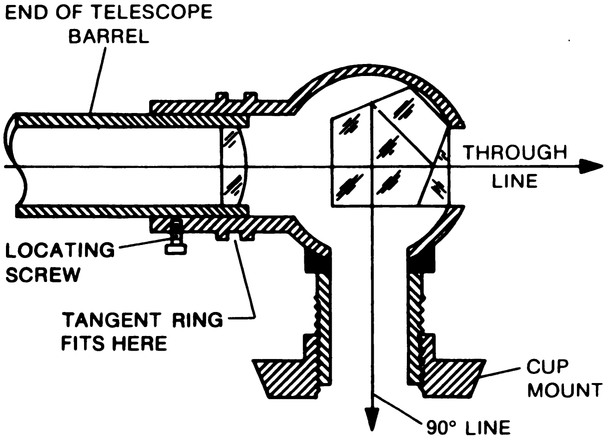


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Figure 2-16.—Schematic view of optical square.

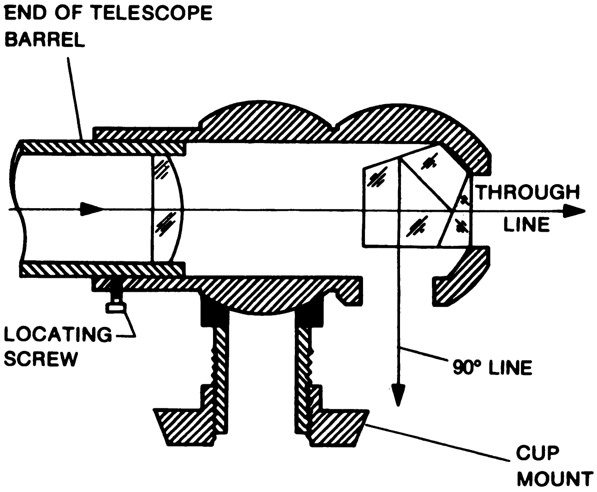

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Figure 2-17.—Schematic view of double sphere optical square.

3. Adjust the bracket so that the center of the opening in the optical square is on the reference line when the instrument is aimed at the center of the objective of a reference telescope. By means of the bracket tangent screw, set the infinity focus on both instruments; then aim the crosslines of the alignment telescope (or line of sight telescope) at the crosslines of the reference telescope.
4. Remove the cap from the 90° opening, close the front window, and aim the 90° line where desired.

Generally, when sighting through the 90° window, the aim in the vertical or roll direction is arbitrary and must be adjusted by hand.

The plane swept by the 90° line can be placed at the desired station by aiming the 90° line at the station mark.

Establishing a Level Reference Line and a Plumb Plane

To establish a level reference line, place a coincidence striding level on the barrel of either the alignment telescope or the line of sight telescope and level the telescope.

To establish a plumb plane, use either the alignment telescope or the line of sight telescope and an optical square with the striding level. When the telescope is level, the through line of sight is also level. The 90° line will sweep through a plumb plane when both the telescope and the optical square are rotated.

Establishing a Vertical Plumb Line

To establish a vertical plumb line, pointed either up or down, mount the alignment telescope in a plumb aligner bracket.

MOUNTING A PLUMB ALIGNER BRACKET AND ALIGNMENT TELESCOPE.—The plumb aligner bracket is shown schematically in figure 2-18. To mount the alignment telescope for a downward sight, proceed as directed:

1. Slide the level collar onto the alignment telescope as far as possible without actual contact between the level collar and the enlarged part of the telescope.

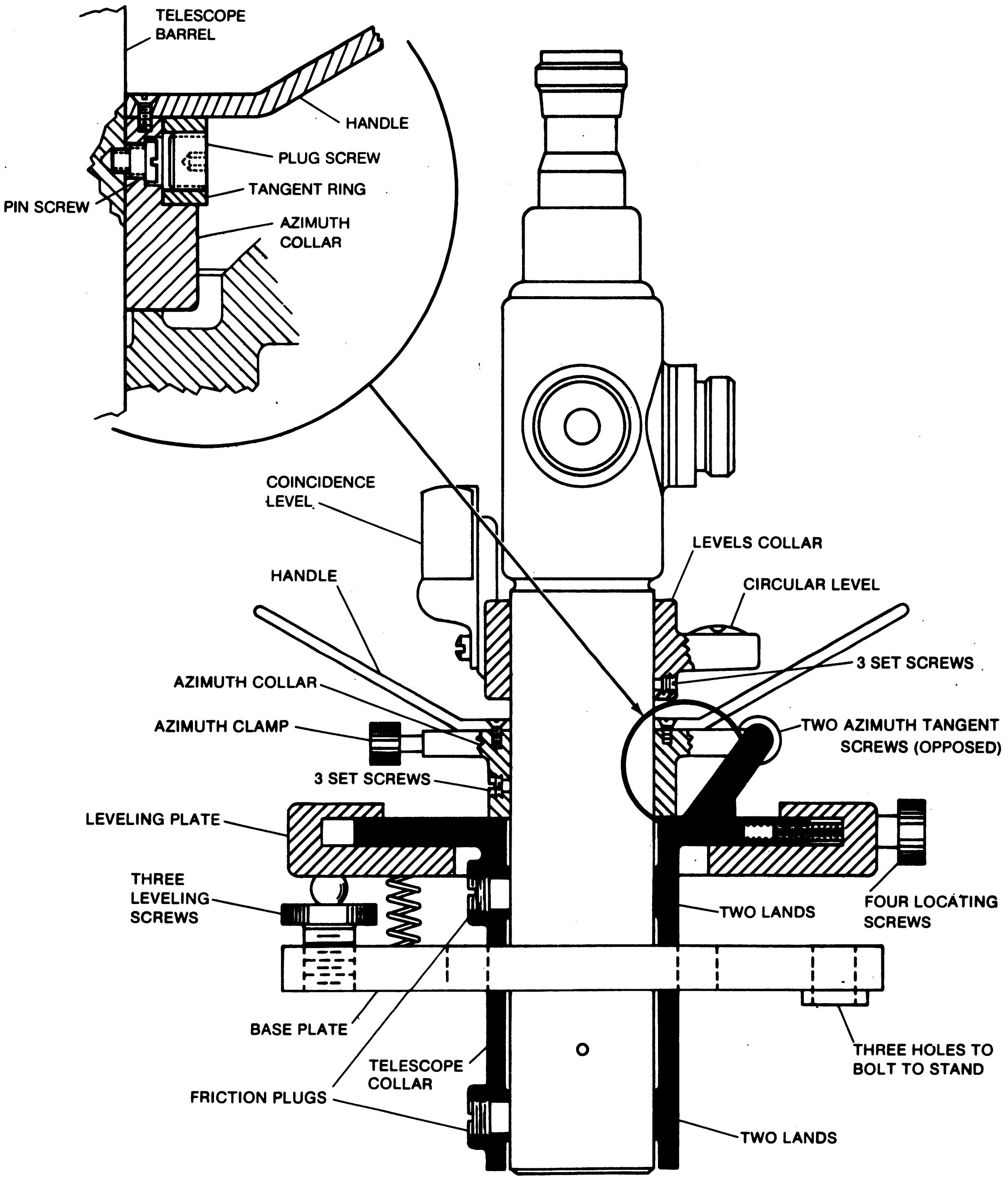

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Figure 2-18.—Plumb aligner bracket with alignment telescope in place.

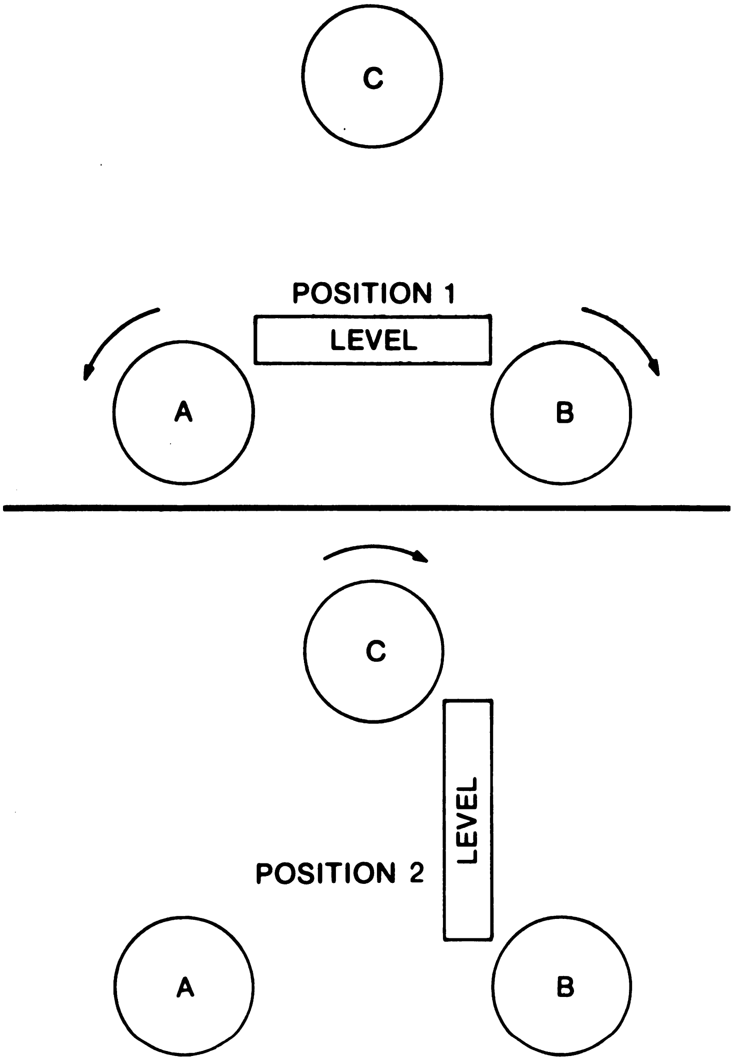

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Figure 2-19.—Method of leveling with three leveling screws.

2. Turn the coincidence level parallel to one of the telescope crosslines; lock it in place by tightening the three socket head setscrews around the circumference of the lower end of the level collar.

3. Make sure that the pin screw is *not* installed in the azimuth collar. Slide the azimuth collar, which holds the azimuth tangent screws and clamps and the handle, onto the telescope as close to the level collar as possible, but free of contact with it. Tighten the three socket head setscrews around the lower end of the azimuth collar.

4. Bolt the base plate, with attached leveling plate and telescope collar, in place on a stand with a hole large enough (4 inches in diameter) to admit the telescope collar. The base plate has three holes around its circumference, each of which extends through a small foot plate for bolting.

5. Lower the telescope, with attached level collar and azimuth collar, into the telescope collar until the bottom of the azimuth collar rests on the three bosses at the top of the telescope collar.

6. Tighten the two large, slot-head friction plugs in the telescope collar only enough to assure proper three-point contact. Excessive tightening of these plugs may either cause deformation of the telescope barrel or prevent tangent motion. Tangent movement is accomplished by means of two opposing screws.

PLUMBING AND POSITIONING THE TELESCOPE.—After the plumb aligner bracket and the alignment telescope have been mounted, take the following steps:

1. Center the circular level bubble with the leveling screws (fig. 2-18). The bubble will move in the direction of any leveling screw that is turned clockwise.
2. Focus on the point over which the plumb line is to be established.
3. Using the four locating screws, bring the crosslines of the alignment telescope on the point. Use the locating screws, which are in tension, in pairs. Loosen one and tighten the one opposite simultaneously and equally. *Leave them firm.* You may have to loosen one or both of the other pair before the telescope will move.
4. Using the handles of the plumb aligner bracket, turn the alignment telescope so that the coincidence level is in line with any two leveling screws (fig. 2-19, position 1).
5. Turn leveling screws A and B simultaneously in opposite directions until the ends of the coincidence level bubble coincide.
6. Using the plumb aligner bracket handles, turn the alignment telescope 90° to position 2.
7. Turn leveling screw C until the ends of the coincidence level bubble coincide.
8. Reposition the crosslines with leveling screws A and B. Check the coincidence level, and repeat the procedure if necessary.

MOUNTING THE ALIGNMENT TELESCOPE FOR AN UPWARD SIGHT.—To mount the alignment telescope for an upward sight, proceed as follows:

1. Mount the base plate of the plumb aligner bracket, with the attached leveling plate and telescope collar, on the stand.
2. Slide the alignment telescope upward through the telescope collar as far as possible without allowing the enlarged part of the telescope to come into contact with the bottom of the collar. Support the telescope in this position.
3. Position the azimuth collar over the alignment telescope.
4. Remove the socket head plug screw located in the azimuth collar (fig. 2-18).
5. Rotate the azimuth clamp (fig. 2-18) until the hole is in line with the hole in the azimuth collar; then tighten the azimuth lock screw.
6. Rotate the combination until it is aligned with the locating hole in the telescope barrel. Screw in the pin screw.
7. Replace the socket-head plug screw over the pin screw.
8. Remove the supports from the telescope. Tighten the three setscrews in the azimuth collar.
9. Slide the level collar over the telescope as far as possible without touching the azimuth collar. Turn the coincidence level parallel to one of the telescope crosslines, and lock it in place by tightening the three socket head setscrews at the lower end of the level collar.
10. Focus the alignment telescope on the point, and level as described above. You may have to install an accessory right-angle eyepiece on the alignment telescope to facilitate sightings through the telescope.

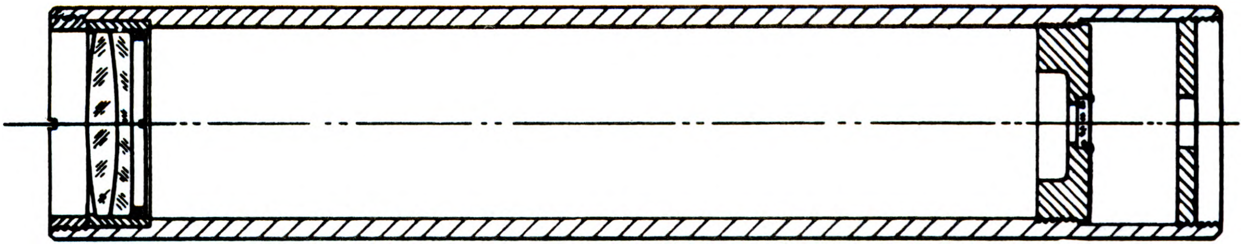
COLLIMATORS

Alignment collimators are used to set other optical tooling instruments parallel to a reference line. The collimator is a telescope that has an illuminated target at its focal plane. The target is graduated in concentric circles. The circles indicate the angular deviation from a line parallel to the line of sight. Collimators are used to measure the amount of tilt of a surface with respect to a reference line.

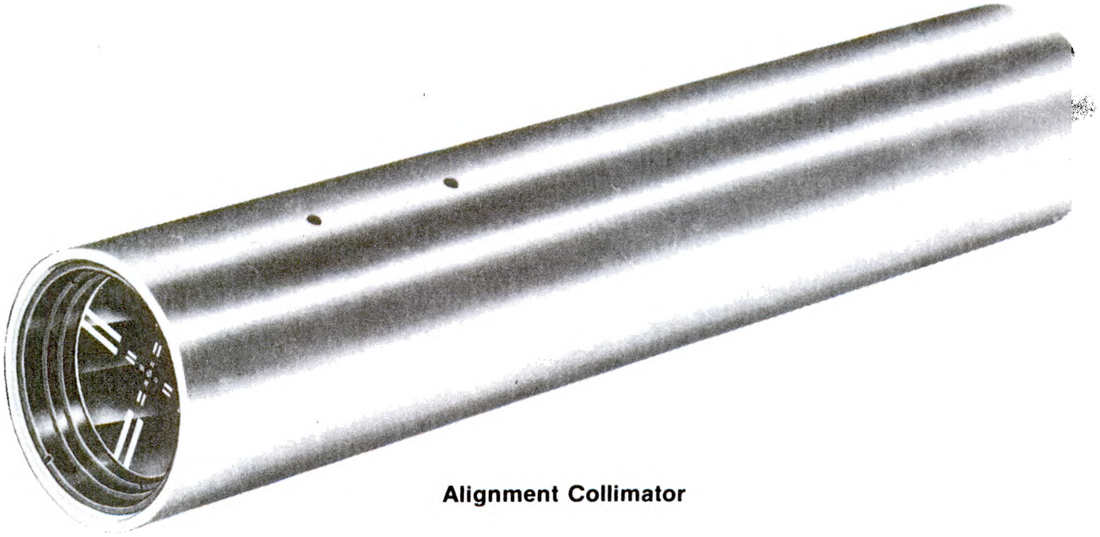
A collimator may contain a cross-hair target in front of the objective lens. This target provides a means of measuring displacement of optical tooling instruments from the line of sight or reference line by autoreflection. The combination of the focal plane target and the front target allows the collinear alignment of the optical tooling instrument axis to the collimator axis.

The collimator is mounted in a tube having the same characteristics as the tube mount for alignment telescopes. A level, attached to a sliding ring, is provided so that the front target hairs and focal target cross hairs may be set vertically and horizontally.

The use of the collimator to achieve collinear alignment of optical instruments requires two operations. First, the optical tooling instrument must be set parallel to the collimator by being focused on the focal plane target; that is, the optical tooling instrument must be focused at infinity. Once parallelism has been obtained, the optical tooling is focused on the focal plane of the target. Focusing depends on the distance between the two instruments. The optical instrument is then adjusted laterally for a zero indication. A recheck of parallelism follows. If any adjustment is made, the process is repeated until



Cross Section of the Alignment Collimator



Alignment Collimator

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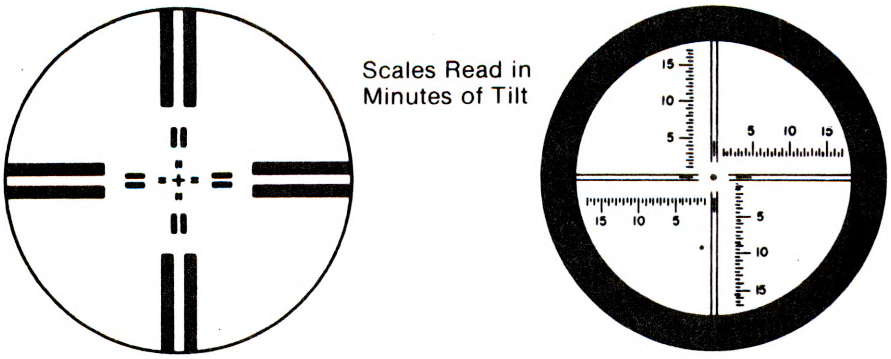
Figure 2-20.—Alignment collimator.



Alignment Target

Tilt Target

148.399X

Figure 2-21.—Alignment target.

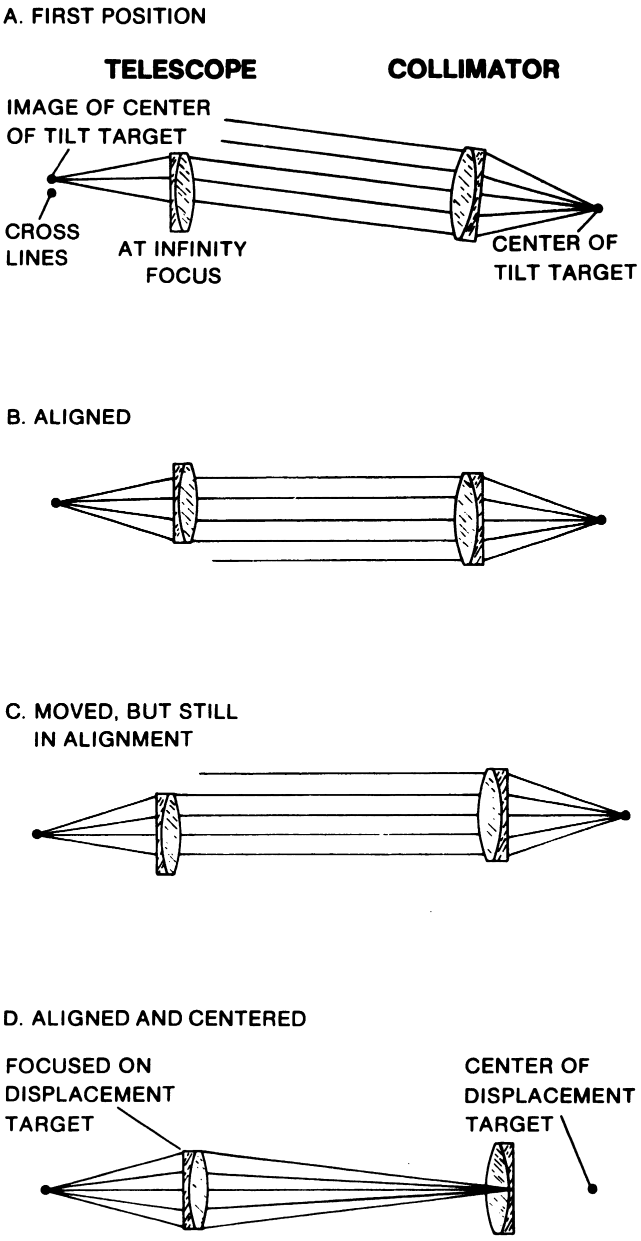
the focus of the optical tooling instrument can be changed from the focal target to the front target of the collimator without the offset on either target.

ALIGNMENT OF COLLIMATOR

The alignment collimator is a device that can be made to coincide with an optical line of sight in direction and position to a very high degree of accuracy. It is usually mounted on a facility gauge or other small jig part so that the tilt and position of the part can be controlled by the line of sight of an alignment telescope. The K & E 71 4010 alignment collimator (fig. 2-20) consists of a hardened, stabilized steel tube with a hard, chrome surface. Its outside diameter is 2.2498 inches +0.0000/−0.0003 inch (Aircraft Industries Association standard). An achromatic lens is mounted near the front of the tube, and a special infinity target is mounted near the end of the tube at the principal focus of the lens. The rear end of the tube is threaded to accept an accessory lamp housing that illuminates the infinity target. The infinity target is graduated every 30 seconds with a total of 18 minutes of arc in four directions from zero. A second, paired-line target is centered on the collimator objective lens.

This alignment collimator is essentially a fixed, infinity-focused telescope without an eyepiece. A reticle or tilt target (fig. 2-21) is located at the principal focus of the lens. Since the alignment collimator is focused at infinity, the light rays emerging from the alignment collimator are focused at infinity. When some of these light rays strike the lens of an alignment telescope or a line of sight telescope, the tilt target can be made to appear in the telescope when the telescope is focused at infinity.

When the alignment collimator is tilted with respect to either the alignment telescope or the line of sight telescope, the center of the tilt target does not appear on the crosslines of the telescope (fig. 2-22, view A). To bring the center of the tilt target on the crosslines of the telescope, the alignment collimator must be directed so that the light rays emerging from it are parallel with the line of sight of the telescope, as shown in figure 2-22, view B. After the tilt has been corrected, the alignment collimator can be moved a small amount parallel to itself. The center of the tilt target will remain exactly on the crosslines of the telescope, as shown in figure 2-22, view C.


A. FIRST POSITION
TELESCOPE
COLLIMATOR
IMAGE OF CENTER OF TILT TARGET
CROSS LINES
AT INFINITY FOCUS
CENTER OF TILT TARGET
B. ALIGNED
C. MOVED, BUT STILL IN ALIGNMENT
D. ALIGNED AND CENTERED
FOCUSED ON DISPLACEMENT TARGET
CENTER OF DISPLACEMENT TARGET

148.400X

Figure 2-22.—Alignment collimator used with alignment telescope.

The alignment collimator also has a displacement target on the objective lens. After the tilt has been corrected, focusing the telescope on the alignment target will cause the target to appear in the alignment telescope or line of sight telescope. The tilt target will then be out of focus and will disappear. The alignment collimator can then be brought on the line of sight as with any alignment target. When the target and the alignment target are both on the line of sight, the axis of the cylindrical surface of the alignment collimator coincides with the line of sight (fig. 2-22, view D).

OPERATION OF ALIGNMENT COLLIMATOR

The alignment collimator is usually mounted on a facility gauge or other small jig part. With this type of mounting, the tilt and position of the gauge or part can be controlled by the line of sight of an alignment telescope or a line of sight telescope. Figure 2-23 illustrates the basic method of positioning a part using an alignment collimator and shop level.

OPTICAL ALIGNMENT ACCESSORIES

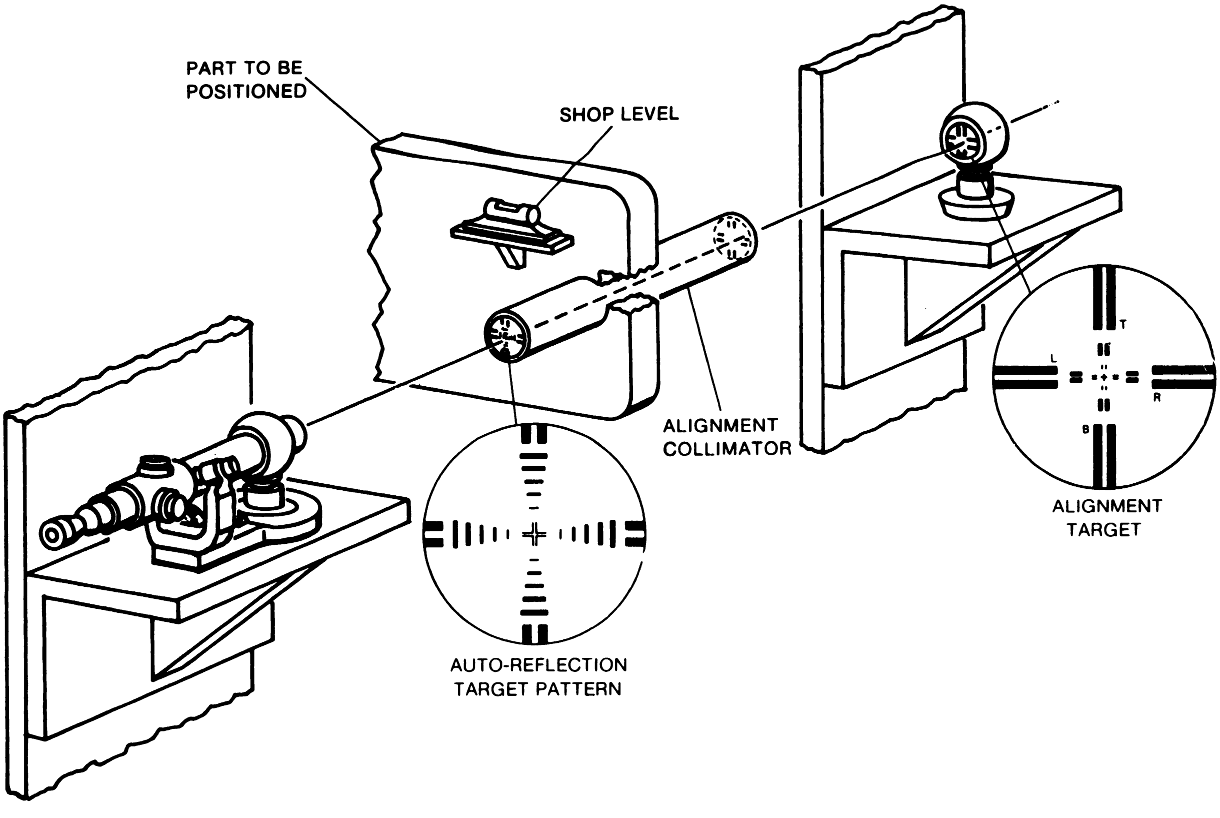
Optical accessories are available for all line of sight telescopes, which give them the ability to perform most of the functions of the alignment telescope.

OPTICAL MICROMETER

The optical micrometer (fig. 2-24) is used to displace the line of sight by some small amount (usually 0.100 inch maximum) for interpolating markings of precision measuring scales. The optical micrometer consists of an optical flat mounted so that it can be rotated about some axis. The amount of tilt is indicated by a graduated drum that reads out in terms of the amount of displacement. Optical micrometers may be built-in devices, as on alignment telescopes, or they may be attachable devices for use on telescopes of various optical tooling instruments. The mechanics of the optical micrometer are illustrated in figure 2-25.

SCALES AND TARGETS

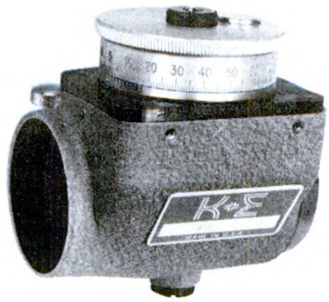
The primary function of optical tooling is to allow you to look at specific objects. Such objects may be scales, targets, and cross hairs or markings on the optical sighting instrument itself (targets on the objective-lens holder). The ability to view markings on the sighting instruments is accomplished by reflection. The markings of precision optical tooling scales are designed to a formula that states that optimum measurement accuracy results if the markings of the target



148.401X

Figure 2-23.—Positioning a part with an alignment collimator and shop level,

(or scale) have certain properties. These include contrast, dark-to-light area ratio, widths of markings for various viewing distances, and ratio of lengths of the markings.

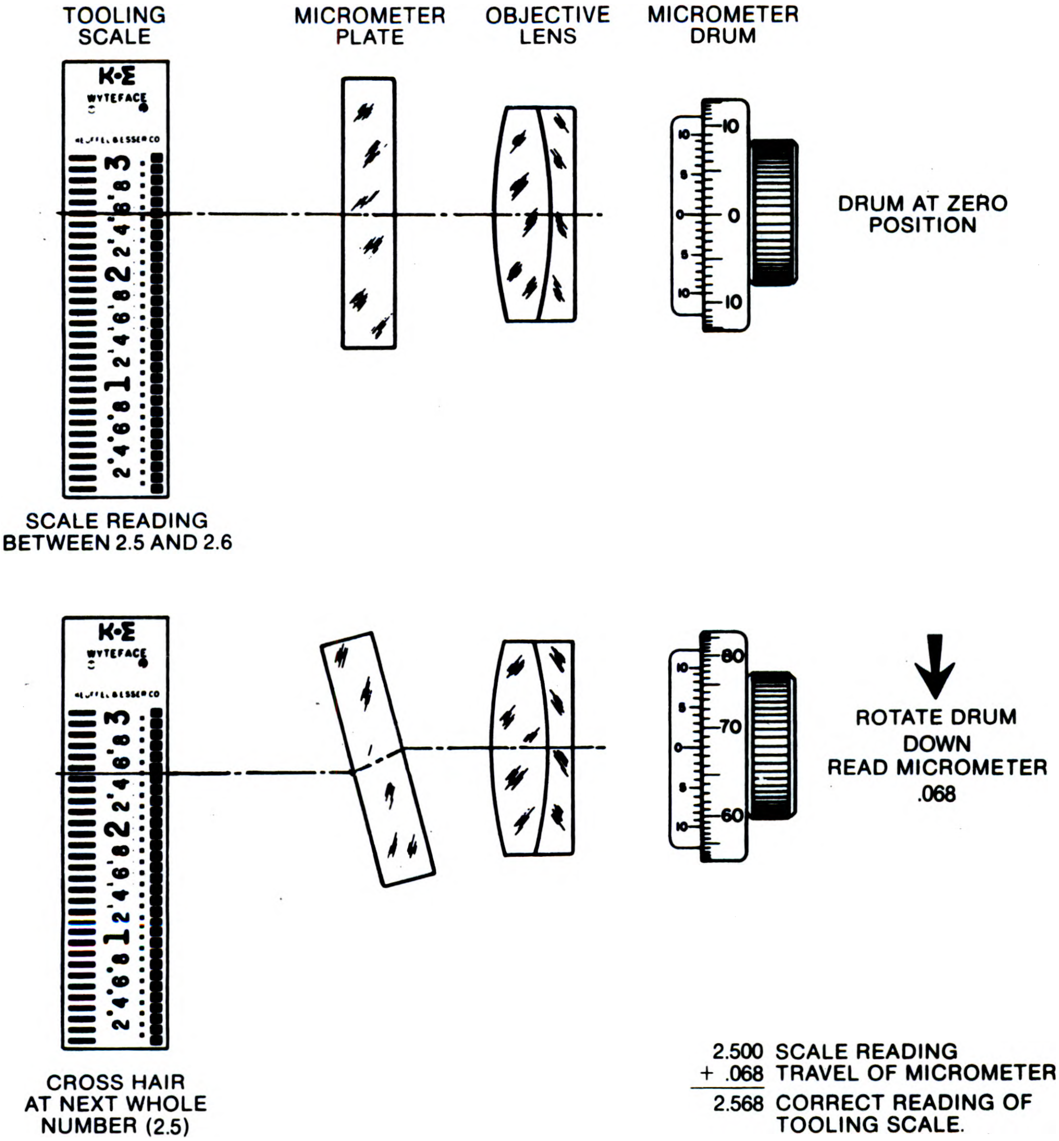


148.402X

Figure 2-24.—Optical micrometer.

Scales

Precision scales are marked every 0.1 inch as measured between centers of the "white-in-black" areas. Four rows of such markings are provided, each row being provided to accommodate a particular sighting range (fig. 2-25). Maximum measurement accuracy is obtained when the cross hair (or filar) of the optical instrument is located midway in a white area between adjacent black areas.



148.403X

Figure 2-25.—Operating principle of optical micrometer.

Targets

Although a number of targets of different types are produced for various applications, two targets are most commonly used. One is the glass alignment target. The other, the open alignment target, is used in cases when several targets are to be set in line, and especially if you need to focus through one target to the next and beyond. Both types of targets have a nominal 2 1/4-inch diameter. They can be mounted in any 2 1/4-inch diameter hole, in a spherical adapter, in a fixture that is indexed to some kind of locator, or in a fixture that centers in a bore.

Targets do not require calibration with the exception of targets designed to be used in spherical mounts.

TARGET HOLDERS

Target-centering devices are available for use with bores greater than 2 1/4 inches in diameter. One of these adjustable target holders can be used with bores of 6 to 60 inches in diameter. Some adjustable target holders use a stick micrometer to center the target in the bore; others use a dial indicator on a sweep arm for the same purpose. If the bores of identical diameters are to be aligned on a day in, day out, production basis, you should fabricate special fixtures rather than use the adjustable target holders.

REFLECTORS

Reflectors are used in autoreflection and autocollimation. The main purpose of either of these functions is to attain alignment in a specific direction. Sighting to a target only defines a line to be established perpendicular to a given surface. This is a critical need when you are checking drive shafts, periscopes, and other alignments.

The most widely used reflector is a mirror. Mirrors for precision work in optical tooling must be constructed from optical flats. The best material for mirrors is quartz with a vacuum coating of silver. A magnetic clamp on a mirror provides a means for performing tasks in the ship and laboratory that would otherwise be impossible. Magnetic mounted mirrors are one-sided mirrors with the face of the mirror parallel to the magnetic mount, unless positioning adjustments are provided. Besides magnetic mounted mirrors, mirrors are supplied with mounts that allow them to stand on various surfaces. The mounts may be fixed or adjustable. Fixed mounts hold the mirror perpendicular to the base of the mount. The mount is also designed to allow the mirror to be set with its length vertical or horizontal. Mirrors in such mounts may be one or two-sided. Adjustable mounts are similar to the fixed mounts, with the exception that the mirror can be rotated through a few degrees.

OPTICAL SQUARING DEVICES

The bending of the line of sight 90° or the establishment of a second line of sight 90° to the first is known as squaring. Two optical tooling devices are used for squaring—the optical cube and the optical square. The right angle prism (fig. 2-26) is the most widely used optical square. It consists of three precision faces in a 90° to 45° to 45° triangle arrangement. A beam directed normal to face 1 will pass unrefracted to the reflecting surface. It will strike this face at 45°, bend through 90°, and exit at face 2 at 90° to the entrance ray.

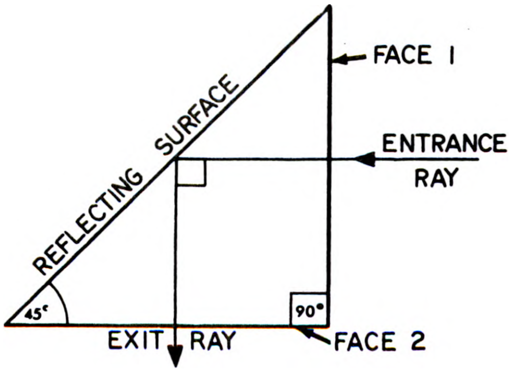


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Figure 2-26.—Right-angle prism.

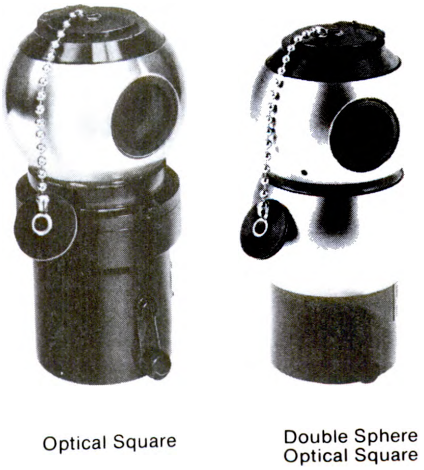

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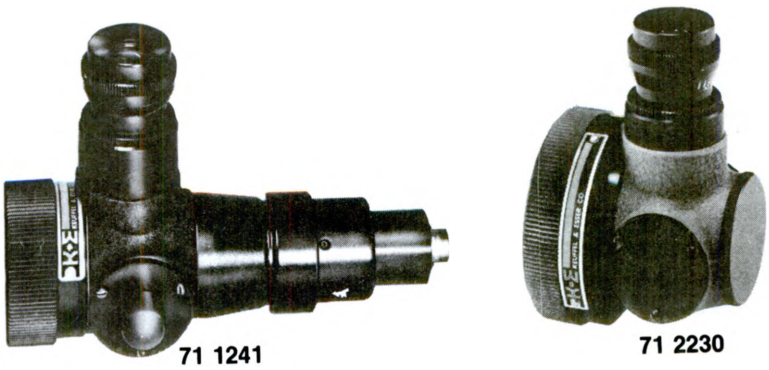
Figure 2-27.—Optical square and double sphere optical square.



148.406X

Figure 2-28.—71 1241 Combination autocollimation, projection, right-angle eyepiece; and 71 2230 right-angle eyepiece.

To perform properly, the entrance ray must be perpendicular to the entrance face. Therefore, the faces at 90° to each other are partially coated to reflect about 30% of the light so that the autocollimator or autoreflection methods can be used to align the prism.

OPTICAL SQUARE DEVICES

Optical squares (fig. 2-27) are available in housings that fit over the front of the telescope. Several varieties are available depending on the specific requirements. Some have both right-angle and straight-through capabilities. Others are equipped with levels for establishing a vertical reference.

EYEPIECES

Several different types of eyepieces (fig. 2-28) are available for optical instruments. They include right-angle eyepieces, right-angle eyepieces with illumination, prismatic eyepieces, and projection eyepieces.

The prismatic eyepiece is a right-angle eyepiece that can be rotated 360° about the optical axis of the instrument for accessibility. An illumination eyepiece produces enough light for autocollimation or autoreflection; whereas, the projection eyepiece provides intense light for projecting the target of the optical instrument to some distant point for observation.

Right-Angle Eyepiece

This eyepiece can be used in place of a standard eyepiece for very low setups or when you are working close to walls, columns, or other obstructions. The right-angle eyepiece maintains a fully erect image and can be rotated through 360° for sighting from any perpendicular angle.

Combination Autocollimation Projection Right-Angle Eyepiece

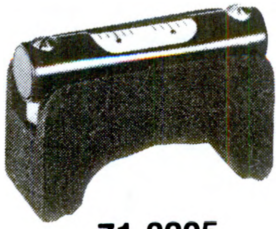
This combination eyepiece can be interchanged with the standard eyepiece to provide the functions of both an autocollimation conversion unit and a right-angle eyepiece. The combination eyepiece can easily be converted in the field from a right-angle system to a straight-through system.

ANGLE READING ATTACHMENT

This attachment fits over the objective end of an alignment telescope. It converts it into an angle-reading type telescope. With the angle reading attachment in place, the micrometer is read directly to 1 second of arc over a range of 50 seconds at infinity only. Maximum usable distance for autocollimation is approximately 30 feet. The infinity setting on the focusing knob is approximately 17 feet.

CROSS LEVEL

This level (fig. 2-29) establishes the reticle crossline of the telescope vertically and vertically and horizontally. The cross level is positioned



71 3205

148.407X

Figure 2-29.—71 3205 Cross level.

by means of a stud that fits into a hole in the barrel of the instrument tube. When the level bubble is centered, the crosslines of the instrument will be vertical and horizontal. The level vial has a sensitivity of 90 seconds of arc per 2 mm of movement.

COINCIDENCE STRIDING LEVEL

This level (fig. 2-30) can be used to establish a level line of sight. It is placed directly on the barrel of the instrument and secured with a spring clip. It uses a coincidence level with a sensitivity of 20 seconds per 2 mm of movement.

AUTOREFLECTION TARGETS

Targets are available for mounting on the front end of the telescope of an optical instrument for use during autoreflection. These targets are designed like other optical targets, except the center is open to keep from stopping down the telescope (fig. 2-31).

AUTOCOLLIMATION CONVERSION UNIT

The autocollimation unit can be used to convert a line of sight telescope into an autocollimating telescope. It includes a light-plug assembly, cord, switch, and fixed 6-volt transformer.

AUTOCOLLIMATION ILLUMINATION UNIT

This unit is used with the alignment telescope and consists of a transformer, cord, switch, and light-plug assembly. It is used with all autocollimation illumination attachments.

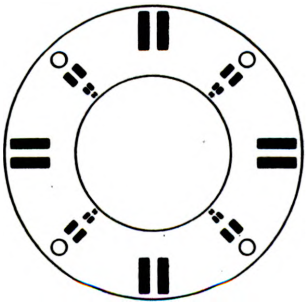
MOUNTS AND STANDS

A large variety of mounts and stands (fig. 2-32) are available for use with optical tooling instruments. They vary from the simple fixed stand to elaborate stands with vertical two-way horizontal and azimuth adjustments. Many of the mounts and stands have hollow centers to allow the instrument to be sighted downwards to a station mark.

The majority of stands are portable tripods that have height adjustment only. The only requirement of a good optical instrument mount or stand is that it be rigid enough to keep the instrument in a fixed position during observations.

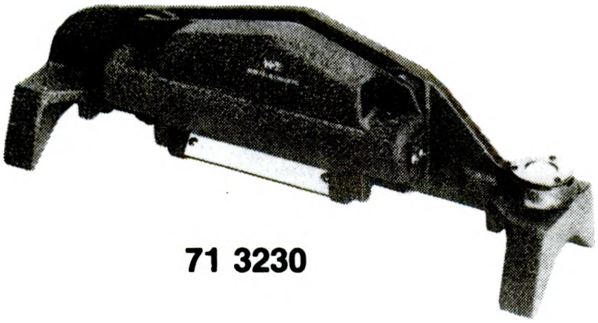
MAINTENANCE

Optical alignment equipment consists of expensive, precision-built devices. Care in handling



148.409X

Figure 2-31.—Slip-on autoreflection target.



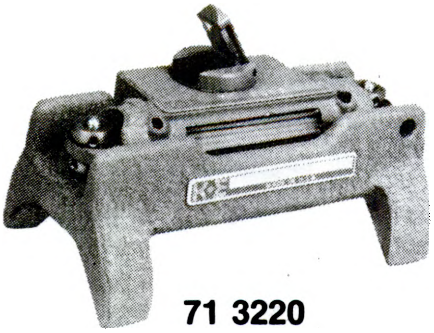


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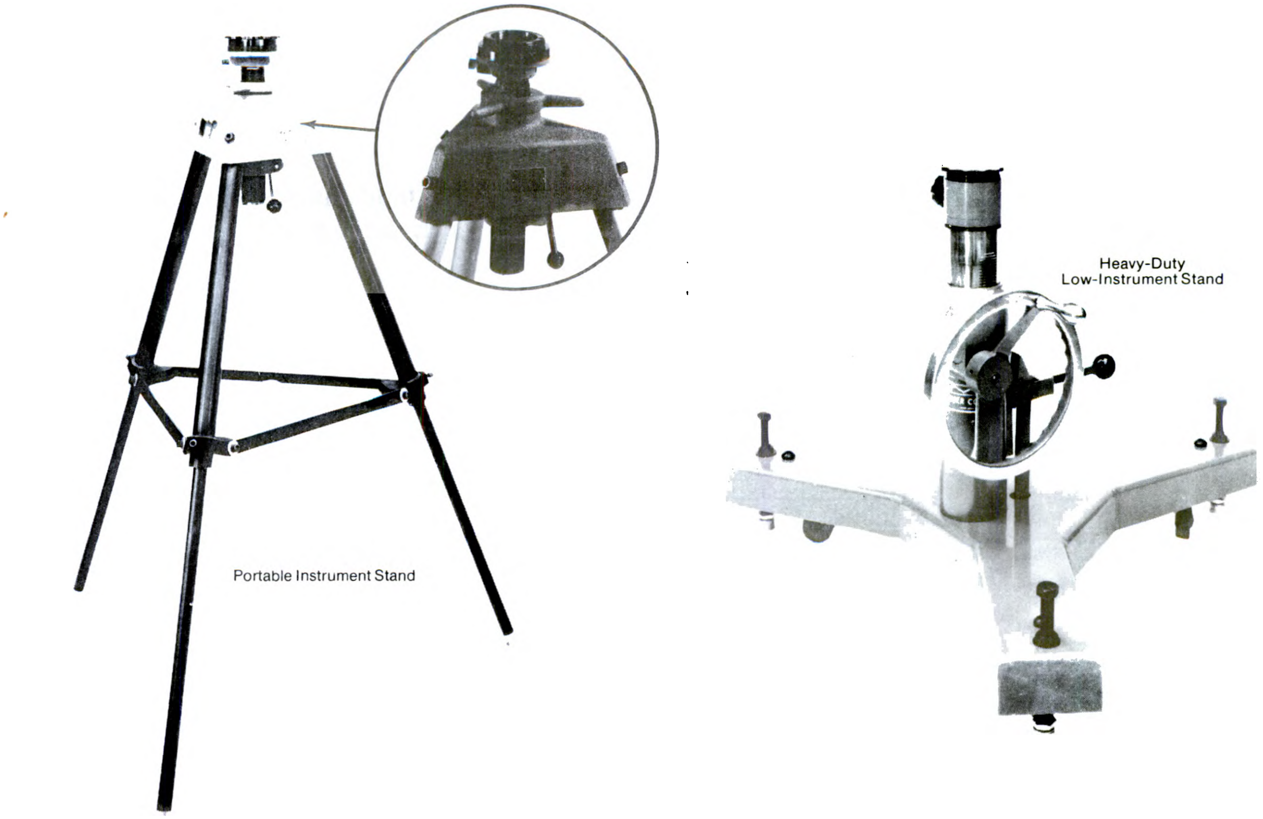
Figure 2-30.—71 3230 Coincidence striding level and 71 3220 Coincidence striding level.



148.410X

Figure 2-32.—Typical instrument stands.

and maintaining this equipment is extremely important to ensure its serviceability at all times.

CARE OF INSTRUMENT

Optical instruments must be given reasonable care. Jarring and vibration may destroy adjustments. The following rules for care of optical instruments are recommended:

1. Always support the instrument in its normal position during storage, use, and adjustment.
2. Never transport an instrument unless it is fully supported on resilient material.
3. Allow the instrument to adjust to surrounding air temperature before operating the instrument.
4. Install any accessories that are to be used with the instrument before making instrument adjustments.
5. When using the instrument, remember that a column of hot or cold air anywhere along the line of sight will destroy the accuracy of the reading.
6. Avoid even partial obstructions along the line of sight when using the instrument. Partial obstructions may make the line of sight unreliable.
7. Protect the instrument from dust as much as possible. Blow or lightly brush dust off; never rub dust or dirt off a lens. If the view through the instrument becomes dim, take the instrument to a competent instrument repairman for cleaning.

TESTS AND ADJUSTMENTS

Alignment collimators contain no adjustment provisions. Alignment telescopes and line of sight telescopes, on the other hand, should be tested frequently. Adjustments should be made only if three successive tests show the same error. Since many adjustments affect other adjustments, they should therefore be performed in the order given to minimize interference.

Adjustment of Alignment Telescope and Line of Sight Telescope

The purpose of this adjustment is to orient the vertical crossline of the reticle so that it lies in a vertical plane when the cross level bubble is in adjustment and is centered. This adjustment is divided into the following two parts: adjustment 1a and adjustment 1b.

The purpose of adjustment 1a is to center the bubble of a cross level when it is mounted on the telescope and also when the cross level is remounted in the reverse direction; for example, when it is turned end for end. To perform this adjustment, proceed as follows:

1. Mount the alignment telescope in V-blocks arranged so that the telescope can be leveled longitudinally and aimed at a well-defined target.

2. Using a coincidence striding level, level the telescope barrel.

3. Mount a cross level on the telescope.

4. Rotate the telescope in the V-blocks until the bubble of the cross level is centered.

5. Reverse the cross level; the bubble should center. If it does not, perform the following adjustments:

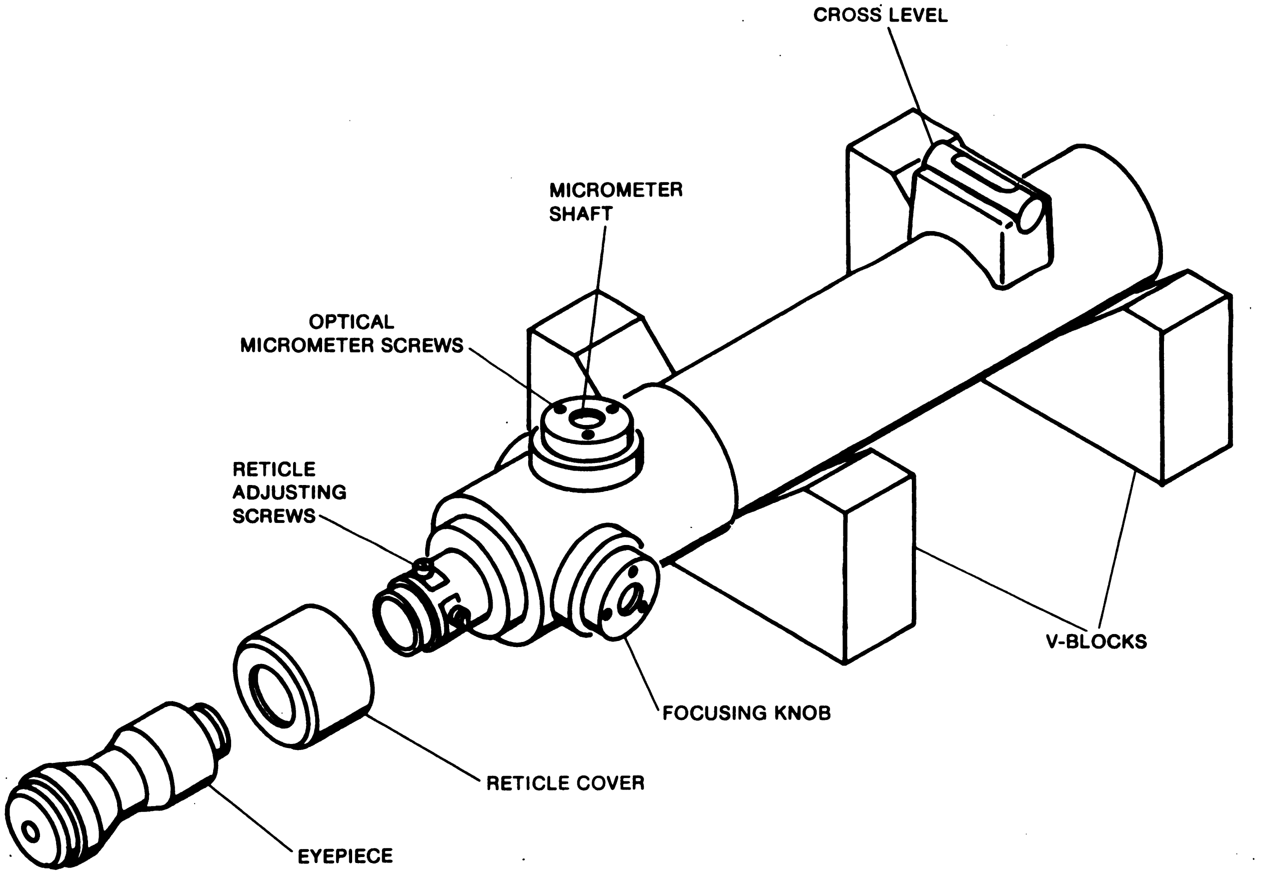
a. Rotate the telescope in the V-blocks until the bubble of the cross level moves halfway back to the center.

b. Eliminate the remaining centering error by adjusting the adjusting screw at one end of the cross level.

c. Repeat 1, 2, 3, and 4 above until all errors are eliminated.

The purpose of adjustment 1b is to align the reticle to the micrometer motions. Proceed as follows:

1. Adjust one of the micrometer knobs on the telescope to either extreme position.
2. Aim the telescope at a well-defined target.
3. Rotate the same micrometer knob to its other extreme position. The crossline should



148.411X

Figure 2-33.—Alignment telescope prepared for adjustment.

remain on the target. If not, perform the following adjustments (fig. 2-33):

a. Unscrew the eyepiece and reticle cover from the telescope. Reinstall the eyepiece. Four reticle adjusting screws are now exposed.

b. Loosen two adjacent adjusting screws. Tap the screws gently to make them slide around the telescope until the crossline remains on the target throughout the full micrometer movement.

c. Tighten the reticle adjusting screws that were loosened.

4. Repeat the above steps until all errors are eliminated.

ALIGNING LINE OF SIGHT WITH LONGITUDINAL AXIS OF ROTATION.—The purposes of this adjustment is to make the line of sight parallel with the longitudinal axis of rotation of the alignment telescope. In performing this alignment, proceed as follows:

1. If no spherical adapter is to be used, support the alignment telescope in V-blocks. If a spherical adapter is used, support the telescope barrel in a cone-type V-block and support the spherical adapter in a cup mount.
2. Unscrew the eyepiece and reticle cover (fig. 2-33). Reinstall the eyepiece.
3. Aim at a distant target, preferably at a collimator reticle.
4. Rotate the telescope 180°. The crosslines should remain on the target. If not, using the reticle adjusting screws, bring the horizontal and vertical crosslines halfway toward the target. In using the screws, be careful to retain tension; otherwise, adjustment 1a will be destroyed.
5. Repeat the above steps until all errors are eliminated.

COINCIDE LINE OF SIGHT WITH LONGITUDINAL AXIS OF ROTATION.—The purpose of this adjustment is to make the line of sight coincide with the longitudinal axis of rotation of the alignment telescope; that is, with the outside surface of the telescope barrel. This is a shop adjustment. To perform this adjustment, proceed as follows:

1. Mount the alignment telescope as in the preceeding section.
2. With the optical micrometers on the instrument set at zero, aim at a target set as close as possible to the alignment telescope.
3. Rotate the telescope 180°. The crosslines should remain on the target. If not, perform the following:

a. Adjust the optical micrometers so that the crosslines move halfway to the target.

b. Loosen the three screws at the top of the drum of the vertical optical micrometer (fig. 2-33 and 2-9). While holding the shaft of the vertical optical micrometer with a finger, turn the vertical optical micrometer scale carefully until it reads zero.

c. Tighten the three screws at the top of the vertical optical micrometer drum.

4. Repeat steps 2 and 3 for the horizontal optical micrometer.
5. Repeat the above steps until all errors are eliminated.

Plumb Aligner Bracket Adjustment

The purpose of this adjustment is to make the coincidence level indicate level when the longitudinal axis of the alignment telescope is vertical. The longitudinal axis is the axis of the surface of the cylindrical section of the alignment telescope. This adjustment affects no other adjustment.

To perform this adjustment proceed as follows:

1. Mount the alignment telescope in the plumb aligner bracket, pointing either upward or downward depending on the direction in which it will be used (fig. 2-18).
2. Level the alignment telescope with the leveling screws 180° in azimuth. The bubble ends of the coincidence level should remain in coincidence. If they do not, perform the following:

a. Rotate the alignment telescope.

b. Eliminate half the error as follows:

(1) Located behind the coincidence level, between the level and the telescope barrel, are three capstan head screws aligned horizontally. The two end capstan head screws are clamps. Free these two screw clamps.

(2) The center capstan head screw turns an eccentric that moves the mirrors forward and back, thereby regulating the position of coincidence. Turn the center capstan head screw as required to eliminate half the error. If this movement is sufficient, set the two end screw clamps. Repeat step 2.

(3) If the movement of the mirrors in step 2 is insufficient to eliminate half the error, note the limits of movement of the adjusting pin when the eccentric is turned as far as possible in each direction. Move the adjusting pin to the half-way point between these limits.

(4) Remove the plug screws on the top and bottom near the viewing end of the cover of the level. The two exposed socket head screws bear against the top and bottom of one end of the bubble-vial tube. Loosen one screw and tighten the other by small increments until coincidence very nearly occurs. Make sure that the screws are tightened firmly when the adjustment has been finished.

(5) Complete the adjustments by repeating step 2.

3. Replace the plug screws and tighten the end capstan head screw clamps.

4. Repeat all steps until all errors are eliminated.

SETUPS

Many kinds of attachments, accessories, and mounting brackets may be used to accomplish any job where optical tooling is required. However, once you have done one alignment job, your confidence will grow. The hardest part of the alignment job is setting up the equipment. With this in mind we are going to do two hypothetical setups. In one, we will adjust the ways of a lathe; in the other, we will adjust the periscope rail.

SETTING UP A LATHE

When setting up equipment to adjust or test a lathe to see if it is in alignment, you must remember how the lathe works.

Since the spindle in the headstock carries the work, the center of the spindle is aligned to the headstock. The carriage rides on the ways. The ways hold the cutting tool at the proper distance from the center of the spindle. This distance must be the same as the full length of the lathe bed. The legs of the lathe must be mounted on a perfectly flat surface; otherwise, the distance of the ways from the center of the spindle will not be exact. This condition will cause the lathe to cut a taper on a short bed lathe. On a long bed lathe, the taper could be tapped or wavy, depending on what legs are out of adjustment. Since the spindle is the main part of the lathe, we have two options as to how to do this setup. Remember, the controlling factor is the equipment that is available in the space. One option is to mount a target on each end of the spindle. The other is to mount the alignment telescope on the outboard end of the spindle and a target on the other.

Two Targets in the Spindle

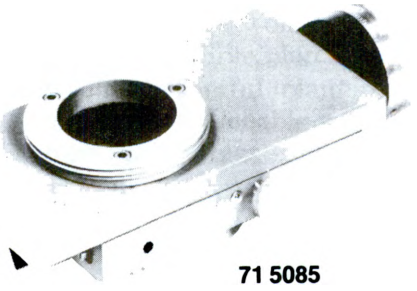
In our hypothetical situation, we will mount two targets in the spindle. We will mount the alignment telescope on a tripod instrument stand. A mirror will be placed at the end of the spindle of the tailstock spindle, and a target will be placed on the carriage so that the target can be adjusted into the center line of the lathe.

As stated before, we need time in setting up equipment. On the front of the alignment telescope, we will mount an autoreflection target, which is held in place with a spring-fitted mounting ring.

This target (fig. 2-31) has two sets of paired-line targets oriented approximately 45° from each other. The first set consists of the finer pairs of close-in sights. The second set consists of widely spaced pairs for long sights. After installation, the autoreflection target must be rotated so that the approximate set of parallel lines is oriented to the instrument reticle lines. We can orient the lines by "eyeballing" at the time of the mounting. The target position will be refined later by observing the reflected image of the autoreflection target pattern in a mirror placed perpendicular to the line of sight of the instrument. In this case, we will use the mirror that is mounted on the tailstock spindle.

We must set up the alignment telescope so that we can sight through the spindle of the headstock. First we will mount a target in each end of the headstock spindle, making sure that they are in the exact center of the spindle. Next we will mount the alignment telescope on the tripod so that we can focus on the two targets. Now comes the long, tedious job of aligning the telescope to the two targets mounted in the headstock spindle.

Since we will have both lateral and vertical movement of the telescope with the instrument stand and the lateral adjuster (fig. 2-34), we can move the telescope to either side and up or down. This is done until the telescope crossline and the two targets are superimposed. Afterwards we will be ready to check and align the lathe bed.



148.412X
Figure 2-34.—71 5085 Precision mechanical lateral adjuster.

The Tailstock

For ease of mounting, we will use a mirror to check and adjust the tailstock. Since the front surface of the tailstock spindle was machined to the spindle, we can mount a magnet-backed mirror on the front surface of the spindle instead of a target. We will focus on the mirror and should have the image of the slip on the autoreflection target superimposed with the alignment telescope crossline. If the image shows horizontal displacement of the vertical crossline only, the problem could be that the tailstock set over needs adjustment; but if the image shows both horizontal and vertical displacement, the lathe bed must be adjusted.

NOTE: In this chapter we deal with the setting up of alignment equipment, not with the actual adjustment required to adjust the lathe.

The Carriage

To check the full travel of the lathe bed, we will use the carriage and cross slide. By mounting a glass target to the tool post, we can adjust the target horizontally with the cross slide. We will then adjust the height by reclamping the glass target to the tool post. By using the glass target, we can refocus onto the mirror to check the tailstock after any adjustment has been made and after we have completed the full travel test. At first you should set up the carriage so that the glass target is close to the headstock. When the target is superimposed with the alignment telescope, then start running the carriage toward the tailstock. Recheck it and make sure that your alignment telescope has not been moved. You do this by focusing the two targets in the headstock. When the lathe is properly adjusted, all four targets will be superimposed with the alignment telescope; the target on the carriage will be superimposed along its full travel of the lathe bed. Each time you adjust the base of the lathe, you must readjust the target on the tool rest.

Aligning the Periscope Rail

To check the periscope rail, we will use an alignment telescope mounted in V-blocks mounted at the end of the rail. Instead of a slip-on autoreflection target, we will use the combination autocollimation projection right-angle eyepiece. First you must unscrew the standard eyepiece from the line of sight telescope and screw the combination autocollimation projection right angle eyepiece in its place. Next you observe the reticle through the eyepiece. If you cannot bring the reticle into sharp focus using the eyepiece focusing ring, use the following procedure to adjust the eyepiece:

1. Set the eyepiece at the approximate center of its movement.
2. Unscrew the entire unit.
3. Loosen setscrew *A* with a 0.035-inch hexagon key (fig. 2-35).
4. Move the lens mount in or out in small increments. Check the reticle focusing after each incremental adjustment.
5. When the reticle can be focused sharply with the eyepiece focusing ring, tighten screw *A*.

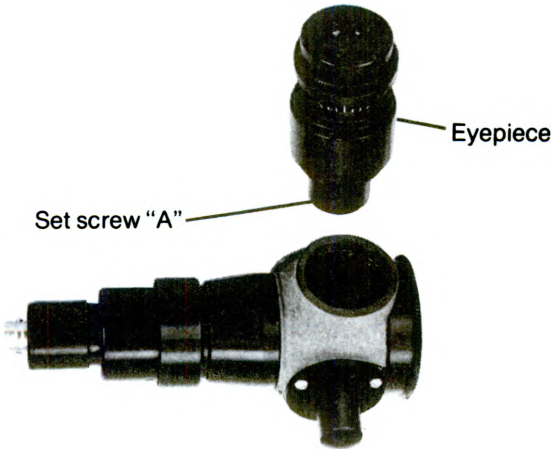


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Figure 2-35.—71 1241 Combination autocollimation, projection, right-angle eyepiece.

6. Focus the telescope at infinity.

7. Hold a piece of white paper approximately 2 feet from the end of the telescope and connect the projection unit of the transformer.

8. Switch on the AC power and observe the projected filament on the white paper. If the filament does not appear sharp, loosen the four projection unit adjusting screws and move the lamp forward or backward until the filament appears sharp.

Adjust the lamp with the four projection unit adjusting screws until the filament appears centered in the projected circle of the field.

Refocus the telescope until the reticle appears sharp on the white paper. The projected circle should be bright and evenly illuminated. If a shadow appears in the field, the lamp (filament) is not centered properly. Readjust the lamp as before.

Replace the paper with a glass, target-mounted rail so that it may be moved along the length of the rail. If you have fixed mounts that are identical, you may mount one at each end of the rail. This will make the process of adjusting the alignment telescope easier. The image can be projected on the center of both targets. This time, however, you do not have to sight through the telescope; just observe the image that is projected on the targets.

After you have adjusted the alignment telescope so that the image can be projected onto both targets, you are ready to slide a third target, mounted along the rail, to the various adjusting points.

You will have to raise or lower the rail or move it sideways so that the projected image lands on the center of the target. One of the advantages of the projection method is that even the untrained observer can see what is happening.

We have shown only two different sets (or procedures) that may be used. However, a particular alignment job may be done several ways. Some of the factors you must take into consideration are space, equipment available, environment, and written procedures that must be followed. As you become accustomed to the various pieces of alignment equipment, you will also become more proficient in making setups and in the amount of time it will take you to do the various jobs.

CHAPTER 3

GUNSIGHTS AND TELESCOPES

The role of the gunsight in naval warfare has been declining steadily since the advent of radar. However, gunsights are still, and will continue to be, installed as an integral part of the shipboard fire control system for reasons that will be explained later. This chapter provides a short account on the growth of fire control as a scientific technique and describes the part that gunsights play in fire control. It also explains the characteristics, operating principles, and maintenance requirements of various gunsight telescopes that are active in the fleet today. This information will help you understand how gunsights are used and how they work. By knowing this, you will be better prepared to perform your duties of maintaining and repairing gunsight telescopes.

THE GROWTH OF FIRE CONTROL

Gunpowder and guns were first used in warfare over six hundred years ago. But, fire control as a specialized technique has been with us for only a relatively short time. Early guns, projectiles, and propellants were crude and ineffective. Fire control at sea was just as crude because of the unreliable ammunition and the irregular, handmade equipment of those days.

Even with the best that the primitive chemistry of that day could produce, something more than improved fire control equipment was needed.

For hundreds of years no substantial improvements were made in ordnance equipment or gunnery techniques. Gunnery required physical bravery, endurance, and a strong back. Efficiency depended on experience, such as firing the cannon at the top of the ship's roll to sweep the enemy's rigging as the ship came broadside and firing at the bottom of the roll to blast the enemy's hull. During the Industrial Revolution of the nineteenth century, ordnance began to turn into precision machinery. Gunnery began to evolve from the art of individual marksmanship into the scientific technique of fire control that we know today.

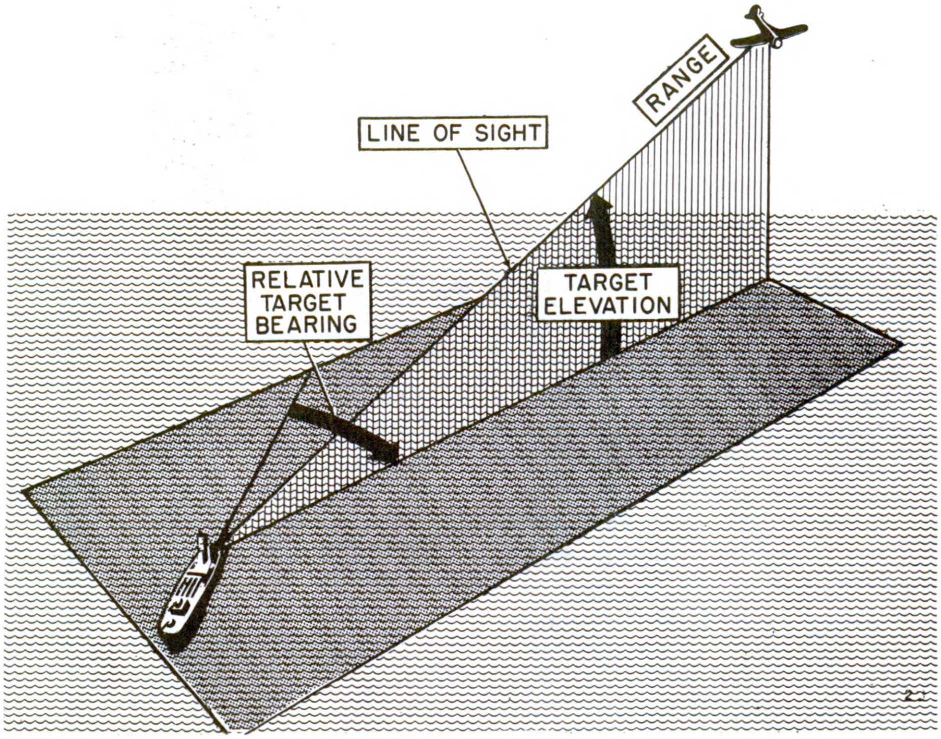
The increases in range at which naval ships have engaged over the years are a good indication of the tremendous development of fire control. You can get a pretty good idea of the tremendous development of fire control when you compare the ranges between ships' naval engagements through the years. During the Civil War, the engagement between the *Monitor* and the *Merrimac* took place at approximately a 100-yard range. (Even at this close range, the gunfire of the two vessels did relatively little serious damage.) In 1905 naval battles were fought at ranges that varied from 4,000 to 6,000 yards. By the end of World War I, improvement in fire control made 24,000-yard ranges practicable. By the end of World War II, the range limit was raised to 40,000 yards because of developments in gun construction, ranging, and computing instruments.

THE TARGET

The most important information you need about any target, whether moving or stationary, is its location relative to the gun firing at it. Knowing the latitude and longitude of a target is not enough. You must have data that can be used to aim the gun. Range and bearing are data needed for aiming at surface targets; range, bearing, and elevation are data needed for aiming at air targets.

The range is the straight line distance along a line of sight to the target (figure 3-1). This distance is measured in yards.

Bearing is the direction of the target in the horizontal plane. This direction may be either a relative bearing (reckoned from the bow of the ship as shown in figure 3-1) or a true bearing (same as the true compass bearing). The direction is given as an angle measured from the reference point (ship's bow or true north) to the target.



84.197

Figure 3-1.—Relative target bearing, range, and target elevation (for an air target).

Bearings are measured in degrees (°) and minutes (′) of arc.

Elevation is the direction of the target in the vertical plane (figure 3-1). Elevation is also measured in degrees and minutes of arc.

A gun can be aimed properly to fire at a stationary target when the target range, the bearing, and the elevation are known. Unfortunately, not many targets are stationary. Besides, even when a target is stationary, your ship usually is not. Your ship's motion must always be taken into account.

Much of the real job of the fire control system comes in at this point. A surface target may either be approaching or moving away from your ship; its bearing with respect to your ship is also constantly changing. Even if the target is at rest while your ship is moving, the effect, as far as the fire control system is concerned, is the same. With air targets, of course, not only the range and bearing change constantly (and fast, in comparison with surface targets) but so does elevation. What you have then is really a problem in prediction to be solved by a computer. The computer figures out where the target is going to be when the projectile gets to it so that the gun can be aimed accordingly.

For the computer to solve the prediction problem, you must first lead the target. You *lead* the target by aiming at a point ahead of the target and in the target's path that the missile and target will reach at the same time. The problem is on how much lead to give the target.

THE PROJECTILE IN FLIGHT

During flight, a gun projectile is subject to a number of forces that influence its behavior and flight path. Since all forces are not of equal importance, any fire control system must take into account those that are most important under the circumstances. The forces to consider are listed below:

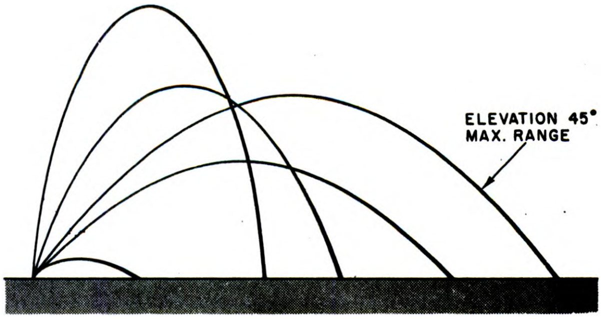
1. Gravity
2. Air resistance
3. Drift
4. Wind

Gravity

Gravity is the most important of these forces. Because of gravity a projectile in flight is always falling. It has no wings and cannot fly. Firing it from a gun cannot keep it from falling (figure 3-2). Suppose you were to fire a projectile at 0° elevation; that is, with the gun perfectly horizontal. Suppose that at the same time someone were to drop a similar projectile over the side from exactly the same height as the gun. The result would be that they would both fall into the sea at exactly the same instant. Although the projectile fired from the gun would hit the water at some distance away, it would fall just as fast as the one merely dropped.

Therefore, the gun is tilted, or elevated, to keep the projectile in flight until it reaches the target. The tilt of the gun is directed toward a point above the target. If the tilt is correct, the trajectory will pass through the target.

The greater the angle of gun elevation, the greater the range—up to a point. Temporarily ignoring air resistance, you find that range increases with the angle of elevation, up to 45°. After that point, increasing the elevation increases the height reached by the projectile, but decreases its range (figure 3-3).



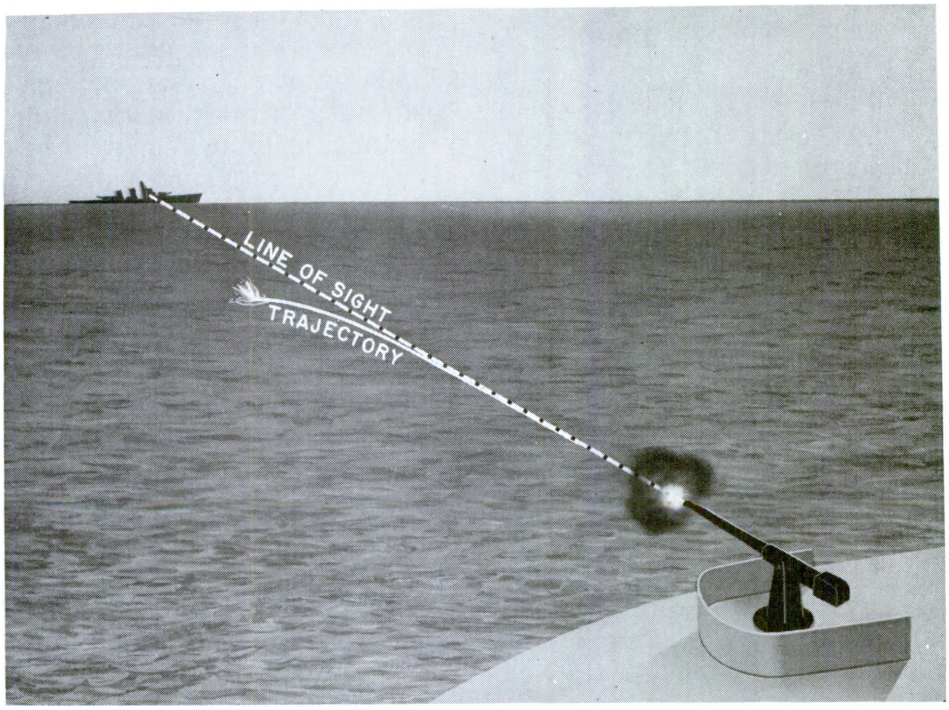
12.3

Figure 3-3.—Theoretical trajectories at various gun elevations (neglecting air resistance).

Air Resistance

Another factor to take into account is air resistance. Many people think of the air in our atmosphere as being thin. But anything that can support 50-ton aircraft and cause meteors to heat up to incandescence as they plummet to earth can't really be considered thin.

A projectile speeding along at nearly a half a mile per second can't ignore air resistance. It doesn't fly through the air; it plows through it.



84.198.1

Figure 3-2.—Firing a projectile from a gun cannot keep it from falling.

The disturbance the projectile makes slows up its flight and causes it to fall at a steeper angle. It cannot go as far and as high as it would in a vacuum.

The way to compensate at least partially for air resistance is to increase range by additional gun elevation. Air density is not a constant like gravity. It varies with altitude and barometric pressure. The amount of compensation necessary, therefore, depends not only on range, but on how high the projectile will go and on the weather conditions at the time of firing.

Wind

The third factor in shaping a projectile's trajectory is the movement of air. The effect of wind on projectile flight depends on how much wind blows across the line of fire (crosswind) and how much it blows along the line of fire (range wind). The effect of range wind is obvious. It tends either to push the projectile along or to blow against it and retard it. Similarly, crosswind will push the projectile either to the right or left, deflecting its path.

Drift

The fourth factor that affects the trajectory of a projectile is drift. Drift is the product of the interaction of three other factors—namely, the clockwise spin of the projectile, the force of gravity, and air resistance. As the spinning projectile moves through the air, it tends to point slightly above the trajectory. The air pressure on its underside develops a thrust that tends to tumble the projectile end over end. But like any other rapidly spinning mass, the projectile reacts to a thrust tending to displace its axis of spin by precessing gyroscopically. In this case, the precession movement is a slow turn to the right. The result is that the projectile's course is deflected to the right relatively slowly at first, but more and more as the trajectory lengthens.

The direction of drift depends entirely on the direction of rotation of the projectile. Drift increases with range but is completely independent of wind.

Because of drift, wind, own-ship and target movements, and so on, you will seldom be able to train your gun directly on the target, except at point-blank range. Just as you must elevate your gun to compensate for trajectory curvature in the vertical plane, you must aim your gun laterally off the line of sight to the target to compensate for the trajectory curvature caused by drift.

APPLYING CORRECTIONS

If projectiles traveled instantly from gun to target and if gravity, air resistance, and other factors didn't distort the projectile's trajectory, fire control wouldn't be a problem to the gunner. However, these factors and their disturbing effects do exist; but there are solutions to the problems they create.

The gunner compensates for the effects of these factors by offsetting the axis of the gun bore from the line of sight so that the gun axis is at an angle to the line of sight. Or, to be more exact, the gunner measures the offset in terms of two angles, one in the vertical plane, the other in the horizontal.

To determine the values of these two angles, you must add the angular corrections required to compensate for all the factors discussed. For example, to compensate for the effects of gravity and air resistance for any given range, you must calculate the necessary amount of gun elevation (angular correction in the vertical plane). To compensate for drift, you must calculate the necessary amount of gun deflection (angular correction in the horizontal plane). To correct for wind, first you must determine the direction and velocity of the wind; then you must calculate the correction necessary in terms of gun deflection and elevation. To lead the target by the proper amount, you must determine the target's range, bearing, and rate of movement in terms of the rate of change of range and bearing. You can then work out in terms of gun elevation, deflection, and rate of change.

The sum of these factors provides the angles that must be added to the target bearing and target elevation angles to give the gun position, or *gun order*, for correct aim. If the data is correct and the gun is properly positioned, the projectile will theoretically and surely hit the target.

SIGHT ANGLE AND SUPERELEVATION

The angle by which a gun is elevated above the line of sight so that the projectile's trajectory will pass through a surface target is called *sight angle* (figure 3-4). This angle is measured in minutes between the axis of the gun bore and the line of sight. As range increases, so does the amount of sight angle.

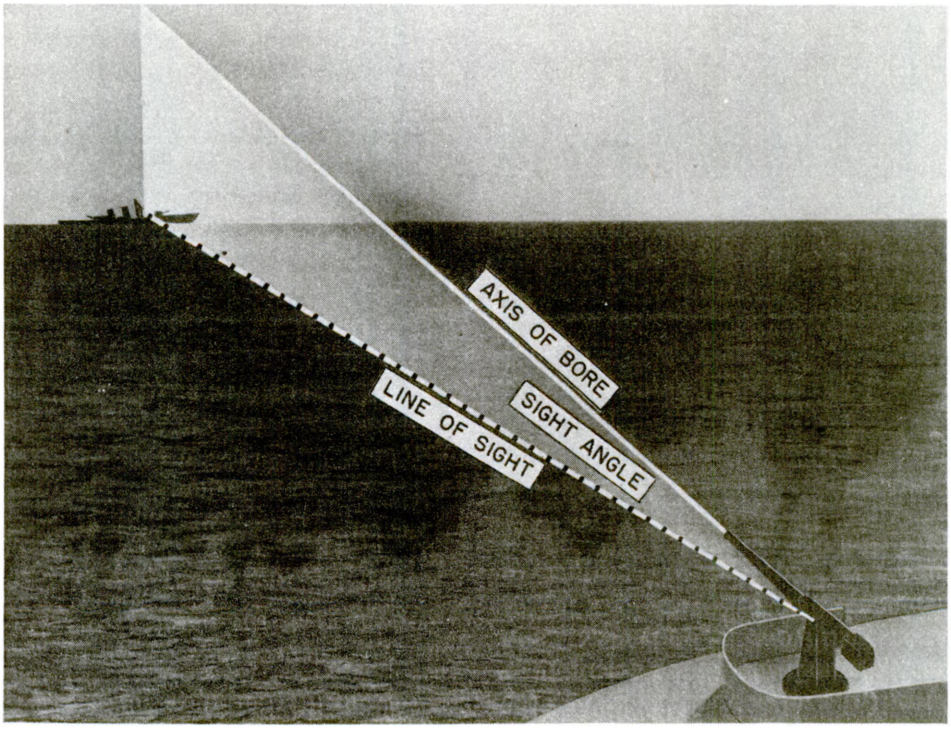


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Figure 3-4.—Sight angle.

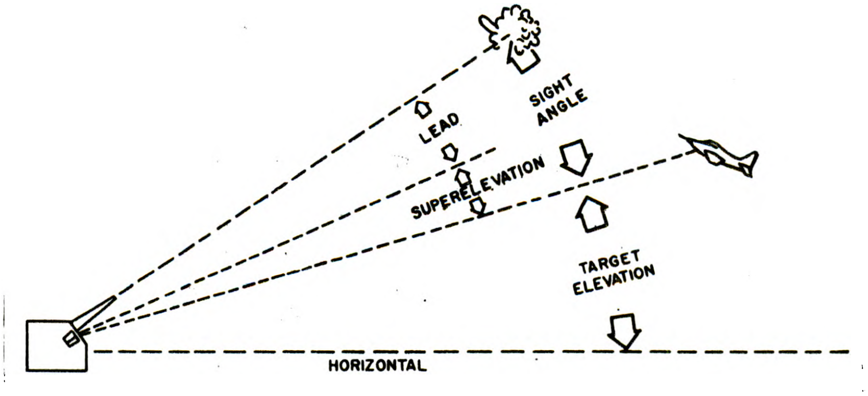

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Figure 3-5.—Target elevation and superelevation.

With air targets, the principle of sight angle still applies. Figure 3-5 shows the sight angle in more detail. It is still the angle by which the gun must be elevated above the line of sight to get a hit. A sight angle is made up of two smaller angles. One is lead. This angle corresponds to the target's relative motion during the projectiles' time of flight. The other angle is superelevation. Superelevation is the angle by which the gun must be further elevated to compensate for the projectile's curve downward because of gravity.

Like sight angle, superelevation increases with longer ranges. But as target elevation increases, superelevation decreases.

SIGHT DEFLECTION

The axis of the gun bore must not only be offset from the line of sight vertically, but horizontally as well. This horizontal angle between the line of sight and the gun bore is known as *sight deflection*. As you know, since a projectile tends to drift to the right, the gun must be offset to the left. Wind is another value to consider in sight deflection. Wind blowing across your line of fire calls for another small offset (to the left in figure 3-5). But the third, and major, value in the sight deflection angle is the lead angle. Lead angle is proportional to the relative motion of the target across your line of sight during the projectile's time of flight.

Unlike sight angle, target elevation, superelevation, and target bearing, which are measured in degrees and minutes, deflection is measured in mils. A mil is a unit of angular measure. There are 6,400 mils in a circle.

INITIAL VELOCITY AND OWN-SHIP FACTORS

So far you've been studying the characteristics of projectile flight and target activity as they affect fire control. But a projectile's course depends on its start. Nothing can be done about its behavior once it leaves the muzzle of the gun. The most important facts you need to know about a projectile's start are how fast it goes (initial velocity) and in what direction.

Initial Velocity

After a projectile is provided with a propelling charge, its chief initial velocity is affected by the following factors:

1. The wear of the gun bore (erosion)
2. The temperature of the propelling charge of the ammunition
3. The weight of the projectile

Own-Ship Factors

The problem of starting the projectile in the right direction is complicated by factors introduced by your own ship. You can calculate accurate corrections for the target and trajectory, and you can determine how the gun must be aimed. However, three factors that make aiming difficult are introduced by the ship itself. These factors are listed below.

1. Ship course and speed. They affect target motion with respect to the ship. Example: Your ship is steaming westward at 10 knots past a stationary target. The effect, so far as fire control goes, is the same as if the target were moving eastward at 10 knots.
2. Roll and pitch. As the ship rolls from side to side and pitches fore and aft, the gun mount tilts and causes errors in elevation and train.
3. Circular steel roller paths on which turrets and gun mounts revolve. They are not exactly parallel to each other or to the plane of the deck.

WEAPON SYSTEMS

The first steps in the functioning of a weapon system are the detection, location, and identification of the target. Ideally, the device performing these functions should (1) detect the target at maximum range; (2) establish the target's location, orientation, and velocity with respect to own ship; and (3) identify exactly what the target is and whether it is enemy or friendly. Such devices should perform with maximum accuracy and minimum delay. It should be equally efficient regardless of the medium in which it operates or the conditions of that medium. It should also operate efficiently regardless of any interference originated by the enemy, friendly forces, or natural causes.

The principal detecting devices now used in the fleet include

1. optical devices,
2. electronic countermeasures (ECMs),
3. radar,
4. sonar, and
5. magnetic airborne detectors (MADs).

All except the last of these depend on detection of radiation. ECMs and radar depend on the detection of electromagnetic radiation, and sonar depends on the detection of sound radiation. MADs detect differences in magnetic fields.

ECM equipment can operate both in the passive or the active mode. It is operated passively when it is used for detection. It is operated in an active mode when it is used to jam enemy electronic detection equipment. Sonar may be used in either the passive or active mode to detect subsurface targets. Its active device produces a radiation that it detects as a reflection from the target. Radar can only be active.

The function of optical devices in weapon systems is to establish target bearing and (for air targets) target elevation. Some optical devices can also measure the range to the target. Except for highly unusual atmospheric conditions, in which light rays reflected from the target to your ship are bent by refraction, the line of sight is truly straight. Optical devices incorporate lens systems and are designed to magnify the image of the target. They extend the capabilities of the human eye in target detection and identification.

Since optical devices depend on visible light reflected from the target, their performance is affected by darkness (unless the target is luminous), fog, and visible obstacles. Optical devices are always passive. They never provide the light that makes the target visible. An attacking ship, however, can illuminate a target by firing gun projectiles that release parachute-supported flares or use aircraft to drop such flares.

At the present time, no optical gunsights for shipboard use employ light radiation invisible to the unaided eye. (Gunsights employing infrared light are used at close range by land forces.)

Radar shares some of the characteristics of optical detecting devices. Except for certain atmospheric conditions, which may affect the paths of the transmitted and reflected pulses, radar pulses travel in straight lines. Radar is quite accurate (to within a degree) in measuring target bearing and elevation. However, it is not as accurate as optical devices. On the other hand, radar is not severely affected by adverse weather and fog and is usable both at night and in daytime.

Radar has disadvantages too. It can be jammed or interfered with by enemy radar transmissions and other countermeasures. It does not provide identification by target silhouette or other visible characteristics. It shows only a blip for a target and may show but one blip for several targets. Compared with optical methods, it requires special skills in interpretation. Radar pulses can be detected by the enemy at greater ranges. In spite of these disadvantages, however, radar is the primary means of detection used in the fleet today.

Normally, target location (elevation, bearing, and range) is determined by a remotely located station. The fire control problem is solved elsewhere. The gun is positioned in elevation and train by power-driven units controlled by signals transmitted from the fire control station.

Well, then, why have sights in gun mounts? Sights are used for two main reasons. One is that the gun mount may not always be under control because of real or simulated casualty. Another is that watching the target through the sights permits a check on the accuracy and performance of the remote-control system.

All gun-mounted, tilting-prism gunsight telescopes have integral systems that provide for sight angles and sight deflection. These systems use two prisms or a mirror/prism combination to direct the line of sight from the target onto the reticle.

The sight angle may be generated either mechanically or electrically by the elevation element (mirror/prism) (figure 3-6). The sight

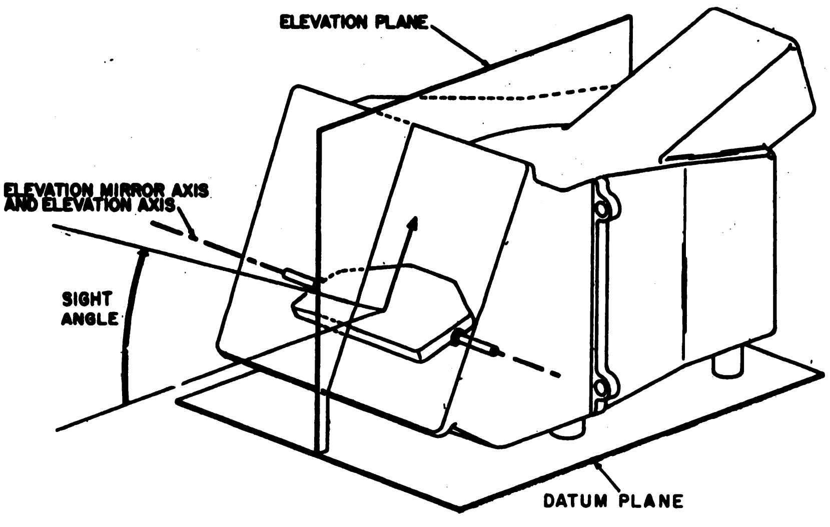

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Figure 3-6.—Application of elevation order in elevation plane.

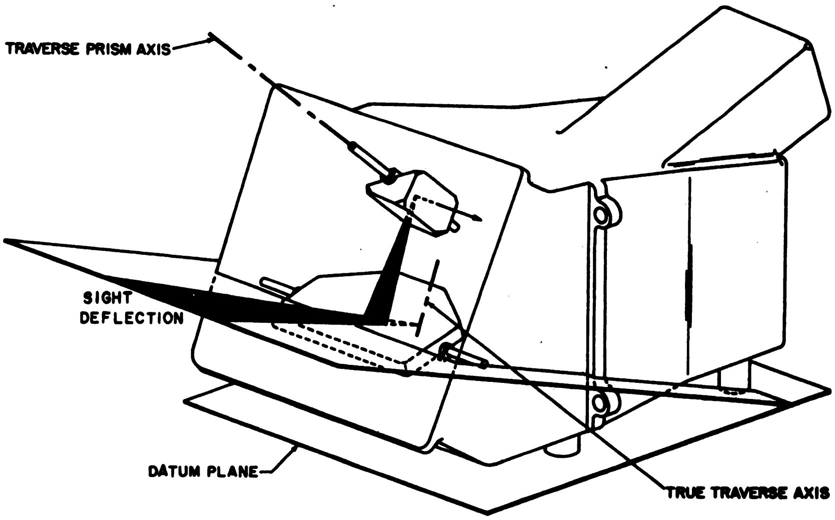

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Figure 3-7.—Application of sight deflection intraverse plane.

deflection (figure 3-7) may also be generated either mechanically or electrically and is produced by the deflection prism.

MK 97 MODS 1 AND 2

The Mk 97 Mods 1 and 2 telescope is a terrestrial binocular that has a movable mirror for elevation and depression of the line of sight. This telescope is the component of Gun Fire Control System Mk 56 that makes possible the acquisition and tracking of air and surface targets. The telescope is mounted on and trains with Gun Director Mk 56. A mechanical input drive from the gun director operates a mirror-tilting mechanism. This drive causes elevation or depression of the line of sight simultaneously with other components in the system.

The Gun Fire Control System Mk 56 consists of the Gun Director Mk 56, radar equipment, tracking control circuits, and computer circuits. The Gun Director Mk 56 mounts a radar antenna for radar tracking, power drives for gun director movement in train and in elevation, and gyro units for stabilizing the system. It also mounts Telescope Mk 97 Mod 1 or 2 for target acquisition and optical tracking and Telescope Mk 104 Mod 0 for primary reference of optical tracking. The optical-radar switch is also an integral part of the gun director.

When the target is acquired visually on the telescope, the gun director is moved by the tracking control so that the target is centered in the telescope line of sight. The optical-radar switch is actuated by the control officer to switch the system to automatic radar tracking. The signals from the gun director, tracking control circuits, and radar equipment are fed into computer circuits, which compute the signal data and transmit orders to gun mounts. During automatic tracking, the telescope is the means of target identification. An error detector is used in case of faulty automatic tracking.

When the radar equipment fails to operate or receives a false echo, the system is switched over to optical; the telescope then becomes the means of tracking. Optical tracking is performed by the telescope operator, who keeps the telescope reticle centered on target by manipulating the tracking control unit. When the radar equipment is back in normal operation or the error in tracking is corrected, the control officer again switches the system to automatic tracking.

Model Differences

Minor differences exist between Mod 1 and Mod 2 telescopes.

1. Mod 2 (figure 3-8) is equipped with an integral pressure gauge that indicates gas pressure inside the body casting.
2. The two eye lenses of Mod 2 are provided with eyepiece plugs for protection.
3. The objective window of Mod 2 is provided with corprene gaskets of three different

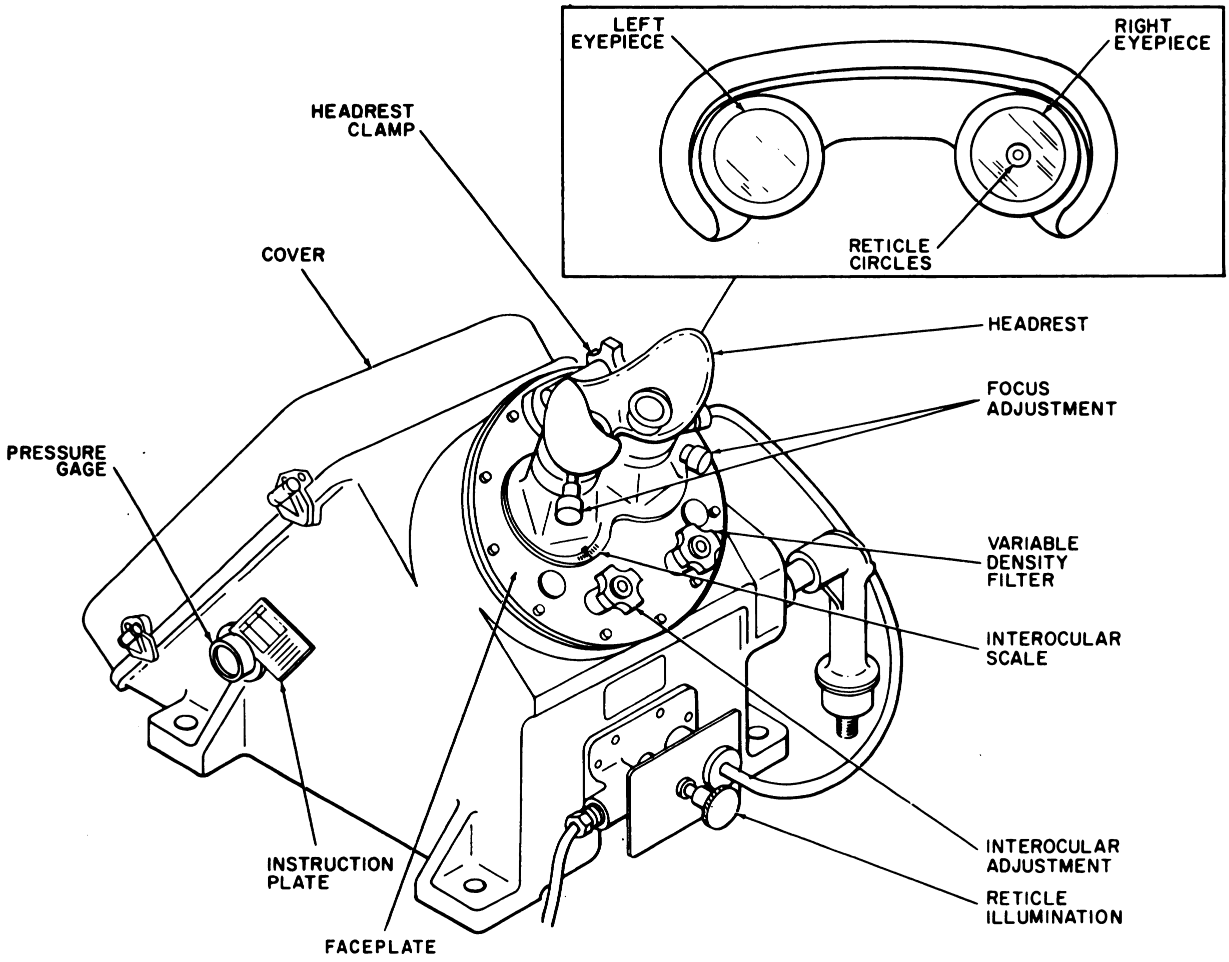

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Figure 3-8.—Telescope Mk 97 Mod 2. Operator's controls and indicators.

thicknesses to compensate for the variations of window plate thickness and to minimize gas leaks through the gaskets.

4. Mod 2 is provided with two eye lens sealing assemblies consisting of a gasket and a retainer, each for better sealing.

The following characteristics apply to the optical systems of the Mk 97:

Magnification—8x

True field—9°

Exit pupil—6.5mm

Eye distance—25mm

Focusing— +1 to −3 diopters
Objective center distance—80.16mm

Physical Description

The body of the telescope is a sealed and pressurized casting. The casting is closed at one end by a covered window and at the other by a faceplate. On the faceplate are mounted two individually focusing eyepieces, an adjustable headrest, and operator control knobs. An opening is provided in the left eyepiece mount to show a solenoid-operated visual signal that indicates when the system is operated with optical tracking. This opening can be closed with a gasket and a threaded cap.

The right eyepiece mount is provided with a housing for reticle illumination light. An illumination rheostat with its control knob is mounted below the faceplate. The mechanical drives are mounted on the right side of the body casting in separate housings. The input drive housing is mounted on that of the mirror-tilt drive.

Optical parts inside the telescope are carried in mounts supported by either the body casting or the faceplate. Optical cells are provided with channels to allow air circulation when the telescope is being dried.

The telescope has four mounting legs integral to the body casting. The finished bottom surfaces of all four legs and the left vertical surfaces of the left legs establish two reference planes, one parallel to and the other perpendicular to the axis of mirror rotation. These planes are used as references during collimation and installation of the telescope.

The Mod 2 telescope is equipped with a pressure gauge mounted on the left side of the body casting in place of the cover plate. The pressure gauge is used to indicate gas pressure within the sealed body casting. It is also used to alert the operator in case of failure of a sealing component.

The telescope consists of several assemblies (figure 3-9). These assemblies include the faceplate assembly, input drive assembly, illumination assembly, mirror-tilt drive assembly, objective mount assembly, and window cover assembly.

FACEPLATE ASSEMBLY.—The faceplate mounts the following subassemblies: ray filter assembly, two rhomboid prism assemblies, and two eyepiece assemblies. The ray filter assembly consists of a pair of variable density polarizing filters and a clear glass compensator for each eye system. These components are mounted in a circular plate rotated by a control knob on the faceplate. The right rhomboid prism is fixed, while the left prism can be rotated by a control knob for interocular adjustment. An index on the housing of the left rhomboid prism reads the interocular setting against a scale graduated in millimeters.

Each eyepiece assembly consists of a mount containing a field lens, a center lens, and an

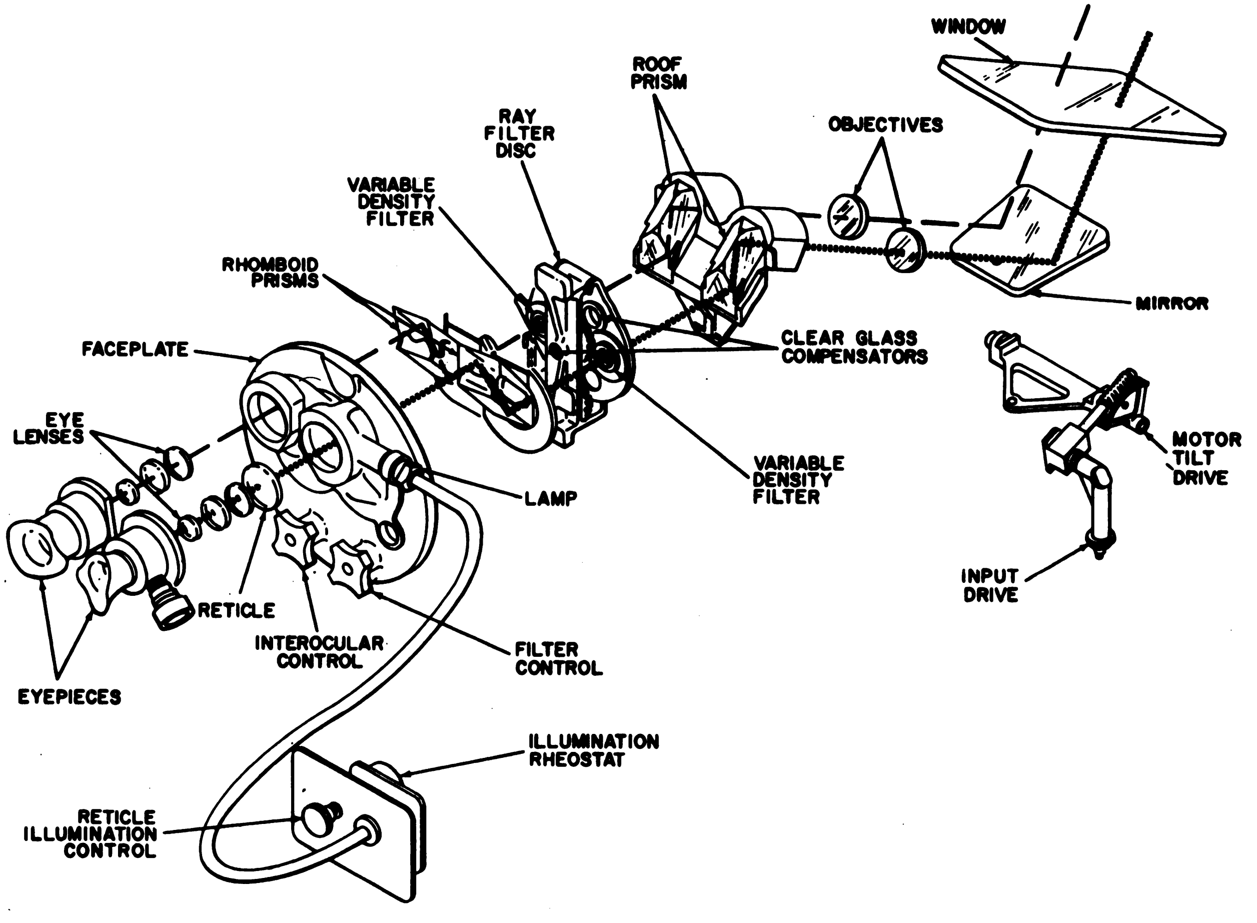

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Figure 3-9.—Telescope Mk 97 Mods 1 and 2. Functional diagram.

eye lens. Each assembly is equipped with a focusing control knob. The right eyepiece is provided with an illuminated reticle for centering the target. The Mod 2 telescope is equipped with eyepiece plugs for protection of the eye lens and with gaskets for eye lens sealing.

INPUT DRIVE ASSEMBLY.—The input drive assembly consists of a vertical shaft, a bevel gear set, and a horizontal shaft, all enclosed in an input shaft housing. The housing is provided with a removable cover plate at the elbow to allow for inspection and lubrication of the gears. The input drive is bolted to the director and coupled to the mirror-tilt drive on the right side of the telescope body.

ILLUMINATION ASSEMBLY.—The illumination assembly consists of a reticle illumination lamp and an illumination rheostat. The lamp is mounted in a housing at the base of the right eyepiece. The rheostat is mounted in a special compartment in the body casting below the faceplate. The rheostat is operated by a control knob. An external cable connects the rheostat to the lamp, and another cable leads from the rheostat to the power source.

MIRROR-TILT DRIVE ASSEMBLY.—The mirror-tilt drive assembly consists of a drive shaft, a sector gear, a mirror mount, and a mirror. The drive shaft has a coupling that engages the input drive and a worm gear that rotates a sector gear. The sector gear is fastened to the right end of the mirror mount shaft. Each end of the mirror mount rotates in a trunnion bearing in the body casting. A cover and gasket over the left bearing seal the body; the right side of the mount is enclosed in the cover for the mirror-tilt drive. A drain plug is located at the low point of the drive cover. The mirror, a first surface reflector of pyrex glass, is clamped and bolted to the mirror mount. The reflecting surface is of evaporated aluminum protected by a coating of reflection-reducing film.

OBJECTIVE MOUNT ASSEMBLY.—The objective mount assembly consists of the mount, two roof prisms, and two main objectives. The objectives are cemented doublets fitted inside the body of the mount; they are equipped with eccentric retainers that fit inside eccentric rings to permit alignment during collimation. The roof prisms are clamped to the mount; they revert the target rays and reflect them upward. The assembly is provided with a light shield mounted inside the body casting above the mirror mount.

WINDOW COVER ASSEMBLY.—The window cover assembly consists of an objective window and a protective cover. The objective window is a plane parallel glass plate held to the body casting by a bezel and sealed with gaskets. The protective cover is hinged to the body casting and secured by a locking handle. A catch on the body of the director holds the cover open when in use. Window Wiper Attachment Mk 15 Mod 0 is supplied separately to keep the window free from moisture. The Mod 2 telescope is provided with corprene gaskets of three thicknesses to compensate for the differences in window plate thickness. The gaskets serve to minimize gas leakage through the window seal.

Functional Description

The functional operation of the telescope describes the optical, mechanical, and electrical functions of the telescope. The optical components of the telescope are described in the order they appear in the path of light from the objective window to the eye of the operator.

OPTICAL OPERATION.—The objective window permits a true field of view of 9°, concentric with the line of sight. From the window the light reaches the mirror. The mirror is a first-surface reflector that can reflect the light incident from 95° elevation to 25° depression and invert the target image. The objective lenses project the reflected light into two channels and direct it into roof prisms. The roof prisms revert the target rays and reflect them upward at an elevation of 25° to the filters.

The polarizing filters control the amount of light passing through the telescope to the operator. When the polarizing axis of the movable plate is parallel to that of the fixed plate, the light transmission is maximum. When the movable plate is rotated 90°, light transmission is minimum. The fixed plates are oriented to minimize glare from water. When filters are not used, clear glass compensators are shifted into the line of sight by means of the filter control knob. The compensators cause practically no light loss but maintain a constant focal length for the system. Stops on the edge of the filter plate and a spring-loaded detent center the filters in the line of sight.

From the filters the light enters the rhomboid prisms. The prisms displace the lines of sight to allow interocular adjustment from 60 to 72 millimeters. Turning the interocular adjustment knob causes the left prism to rotate about an axis normal to its entrant face so that the distance varies between the exit faces of the prisms.

From the exit faces of the rhomboid prisms, the light is directed to the eyepieces. The internal focusing type of eyepiece consists of two movable cells, each holding a cemented triplet and a cemented doublet. The eyepieces are sealed by single eye lenses that are fixed into the mounts. Adjustments from +1 to −3 diopters can be made by a knob mounted on each eyepiece. An illuminated reticle is located at the focal plane of the right eyepiece. The reticle serves as a reference mark in centering the target in the field and consists of two concentric circles. The true field of the inner circle is 3 mils; that of the outer circle is 15 mils.

MECHANICAL.—The mechanical drive for the telescope consists of an input drive and the mirror-tilt drive. The input drive transmits shaft rotation from the gun director to the mirror-drive to coordinate the line of sight of the telescope with that of the gun director. The mirror-tilt drive transmits the shaft rotation from the input drive to the mirror mount. No backlash device is provided for the mirror-tilt drive. A mechanical stop consisting of a series of tongued washers limits the mirror movement from 100° elevation to 30° depression.

ELECTRICAL.—The right eyepiece is provided with an illuminated reticle for centering the target. The power for the illuminating lamp is provided by a six-to-eight-volt power supply. The illumination rheostat is used to vary the intensity of illumination according to the operator's need. A red filter, which improves the dark adaptation of the operator's eyes, is provided to illuminate the reticle.

OPTICAL SHOP MAINTENANCE CHECKS

Optical shop maintenance checks are performed to enable optical shop personnel to locate such malfunctions as optical maladjustment, faulty mechanical action, poor illumination, or pressure failure. If the telescope fails any of the operational tests, the malfunctioning assembly or component is removed from the body casing and repaired or replaced. The following is a list of checks you may be required to conduct to correct or prevent malfunctions.

1. For interocular adjustment, measure the interocular distance with a metric scale between any two corresponding points on the eyepiece. Check the measurements against the *interocular scale* reading. They must correspond within 0.25mm and must range from 60 to 72mm.

2. To adjust the eyepieces, first adjust an auxiliary telescope Mk 1 by bringing a clear distant target into sharp focus. Then place its objective on each eyepiece and focus the eyepiece on a target more than 1,500 yards away. Diopter zero must be located within 0.25 diopter of sharp target focus, and the two eyepieces must agree within 0.2 diopter. Each eyepiece must be capable of being focused from +1 to -3 diopters without binding or looseness.

3. Using the auxiliary telescope, see that the reticle, located in the right optical system, is in focus when the target is in focus. If it is not, parallax must be corrected.

4. Turn the *reticle illumination* control to see that the rheostat operates throughout the full turn of the knob. The reticle should be evenly illuminated through all stages of the adjustment.

5. Make sure that the telescope is free of internal reflections, or "ghosts."

6. Set and adjust a dynameter Mk 2 against each eyepiece to bring the circle formed by the emergent pencil of light into focus on the ground glass reticle. The diameter of the exit pupil should be 6.5mm.

7. Rotate *filter* control to determine that the detents are operating smoothly without looseness and that the detent action holds each filter firmly in the line of sight. As the knob is rotated counterclockwise, first the clear compensator, then the variable density filter, from minimum to maximum density, should appear.

8. Sight Telescope Mk 104 Mod 0 on a stationary target and check Telescope Mk 97 Mods 1 and 2 for agreement in alignment. The target should be held within approximately 1/2 mil of the center of the reticle.

9. Make sure that all optical glass is clean and free of obscuring defects, with no condensation on internal glass surface.

10. Inspect the exterior for scars and for the condition of the paint.

11. See that the body seal of the telescope has not been broken.

12. (Mod 1 only) Check gas pressure by removing the smaller (air inlet) screw in the air valve and screwing a test gage into the hole. Back off the larger screw to get a pressure reading between 3 and 5 psi.

13. (Mod 2 only) Charge the telescope with gas to an approximate pressure of 4 psig and and observe it for leaks. If leaks are found, they should be eliminated by proper repair, such as correcting the gasket sizes, or drilling blow holes and filling them. Locate and correct all leaks until no further leakage is observed.

14. Inspect the bottom surfaces of the four legs and the left vertical surfaces of the left legs for damage or foreign matter that might impair their accuracy as mounting surfaces.

15. Rotate the input drive shaft using a torque bar. The shaft should rotate at about 30° to 45° a second when five inch-pounds of torque is applied.

16. Rotate the input shaft for the full extent of the travel. The line of sight should sweep through the arc from 100° to minus 30° with 32 1/2 turns of the input shaft. At any angle of elevation or depression, the movement of the line of sight with respect to the plane established by the mounting surfaces of the legs must correspond within 3 minutes of arc to the amount of input shaft rotation.

17. Rotate the input shaft and check mirror motion. Backlash must not exceed 1° of rotation of the input shaft without mirror motion. Input shaft rotation of 1° should produce 0.67 minute of elevation or depression of the line of sight.

Component Replacement

Component replacement takes place when optical shop maintenance checks indicate that such procedure is necessary. To reach defective components inside the body casting of the telescope, you must break the seal and partially disassemble the component.

NOTE: Before you proceed with component replacement, be sure you have on hand all the replacement parts you will need, as well as a new seal (gasket or O-ring), to restore the telescope to proper operation.

Disassembly Procedure

Disassemble the telescope only to the extent necessary to effect the repair. Spare parts for the telescope are listed in APL 49400166. This list, as well as spare parts and replacement parts, may be requisitioned from the Naval Ship's Parts Control Center, Mechanicsburg, Pennsylvania 17055. During disassembly, refer to chapter 7 of NAVSEC OP 1857. Before starting disassembly, slowly bleed the internal gas pressure of the telescope. Remove the window by attaching a plate glass suction cup to the window to lift it out of the casting. Then cover the mirror immediately with lens tissue and a cardboard or metal shield to avoid damage to the top surface.

Component Repair

You should repair the components of the telescope to restore them to a condition comparable to new parts.

Optical Components

Repair or replace optical components of a telescope following the procedures listed below.

1. Examine each optical element for defects or signs of deterioration.

2. Repair all optical elements in which cement has deteriorated in accordance with OP 463.

3. Examine all optical surfaces for scratches. (Scratches on glass located in parallel light are not serious.)

4. Replace all scratched optics located in convergent light, particularly in the reticle. Replacement objectives must be matched sets.

5. Return polarizing plates to their proper positions so that their indices correspond at minimum density.

Mechanical Components

To repair or replace mechanical components of a telescope, perform the following procedures:

1. Examine the mechanical components of each assembly for smoothness of action and for working condition. Look especially for burrs.

2. Repair or replace any faulty components.

3. Inspect mounting surfaces and carefully refinish those that are sufficiently scarred to cause poor fit at reassembly.

4. Check all mounts to see that they are secure.

5. Use appropriate thread chasers to remove dirt, corrosion, or burrs from threaded parts.

6. Use alcohol to remove old shellac from around screws.

7. Use lubricants sparingly on mechanisms. Do not use oil because it may vaporize and cloud optical elements.

Reassembly Procedure

Reassembly is the reverse of disassembly.

When reassembling a telescope, perform the following procedures:

1. Check and match all bench marks made during disassembly to ensure proper orientation and fittings of components.

2. Replace all used gaskets, packings, and O-rings.

3. Reseal the components with fresh wax.

Collimation

Collimation of the Mk 97 telescope consists of leveling the mirror, setting zero diopters, and adjusting the objective eccentrics to align both lines of sight with the collimator.

To level the mirrors, install both the mirror-tilt drive assembly and the mirror in the telescope body. Clean the mounting feet and set the telescope on a large surface plate. Use a surface gage and a sensitive dial indicator (.0001-inch graduations) to establish parallelism between the surface plate and the mirror.

NOTE: Since the mirror is front-surface aluminized, use extreme caution when cleaning and leveling. The dial indicator should contact the mirror only at the extreme edges.

Operate the mirror-tilt drive input shaft to establish parallelism between the surface plate and front-rear mirror surfaces. If you note any error between the left-right surfaces, carefully scrape the mirror mount to eliminate the error. The tolerance for mirror parallelism is 0.00075 inch.

Use standard techniques to set zero diopters and equal focusing of both eyepieces. Use a stereo comparator when adjusting the objectives to align both lines of sight with the collimator.

Complete procedures for overhaul, collimation, and sealing/drying of the Mk 97 telescope are found in OP 1857.

MK 100 MODS 0 AND 1

Telescope Mk 100 Mods 0 and 1 are used in Gun Directors Mk 67 and Mk 68, which are parts of Gun Fire Control System Mk 67 and Mk 68, respectively. Telescope Mk 100 is used to establish the line of sight of the directors. Two telescopes are used with Director Mk 67. Only one is used with Mk 68. In the Mk 67, one telescope is at the tracker station and the other is at the assistant gun director station. Gun Director Mk 68 has only one telescope. It is located at the tracker station. Each telescope is rigidly attached to an optical shelf that establishes the position of the telescopes to the director. Both Directors Mk 67 and 68 are stabilized in cross-level to enable elevation angles to be measured in the plane normal to the earth's surface.

Tolerance

Telescope Mk 100 is required to meet the following tolerances with respect to elevation and depression of the line of sight.

The plane established by the line of sight from −25° to +95° must be perpendicular, within 1 minute of arc, to the plane formed by the machined surfaces on the 4 feet of the telescope body casting.

The plane established by the line of sight from −25° to +95° must be parallel, within 1 minute of arc, to the plane formed by the two vertical machined surfaces on the left feet of the telescope body casting.

At any angle of elevation or depression, the elevation of the line of sight with respect to a plane formed by the four horizontal machined surfaces on the feet of the telescope body casting must correspond within 2 minutes of arc to the amount of rotation of the input shaft.

Coplanarity of the four mounting pads must be such that the line-of-sight requirements are maintained under any bolt-load condition. With any three pads in contact with a common flat surface, the space between the common surface and the remaining fourth pad cannot be more than .0015 inch.

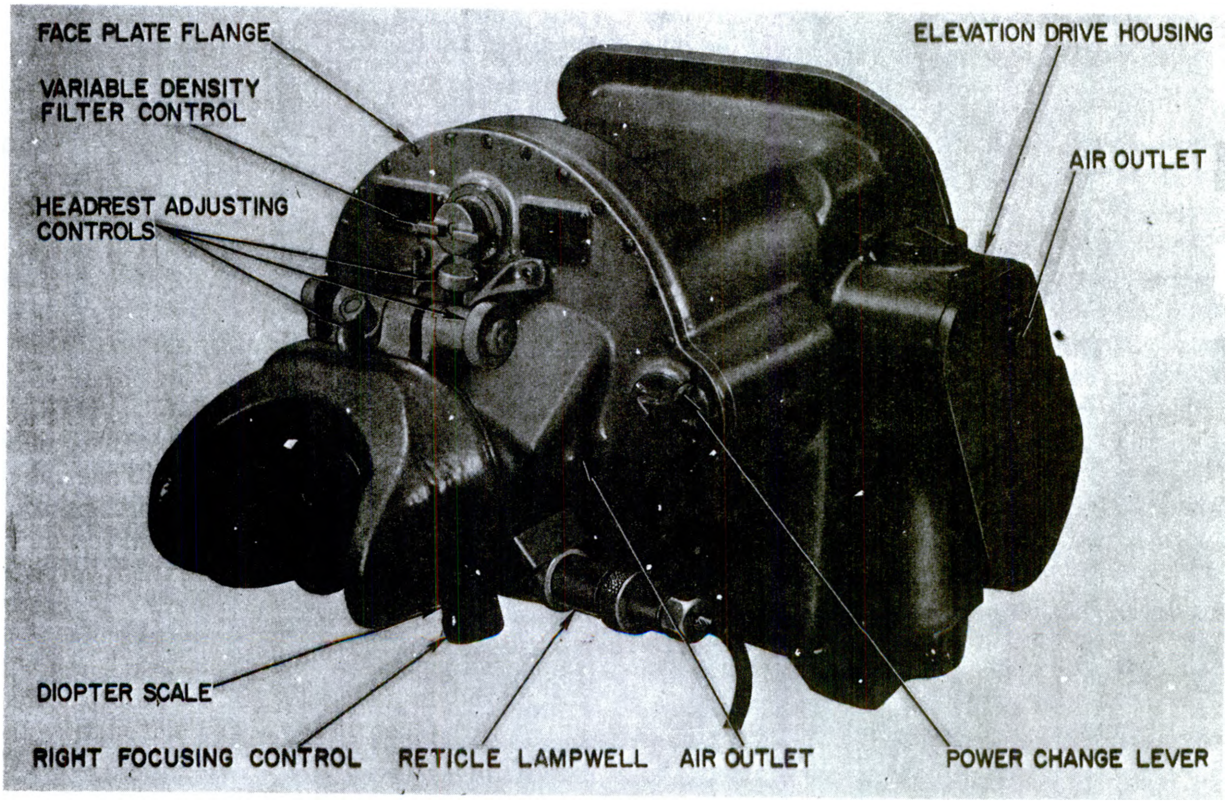
Description of Components

Telescope Mk 100 (figure 3-10) is a focusing prismatic binocular instrument. It has a rotating objective mirror for elevating the line of sight. A change of magnification arrangement in the instrument permits selecting either six- or ten-power magnification. A filter system serves both right and left optical systems. It consists of a pair of plane glass plates and a pair of double polarizing plates in a circular mounting. The eye lens assembly can be focused within a range of +1 to −2 diopters.

Operating controls are provided for changing magnification, for individually focusing eyepieces, and for interpupillary adjustment. A rheostat, mounted on the director structure, controls the illumination intensity of the telescope reticle. A single filter control operates the density adjustment. Operation of the control shifts filters into and out of the optical systems to vary filter density. When the filters are shifted out of the optical systems, clear glass plates are inserted into the optical path in place of the filters.

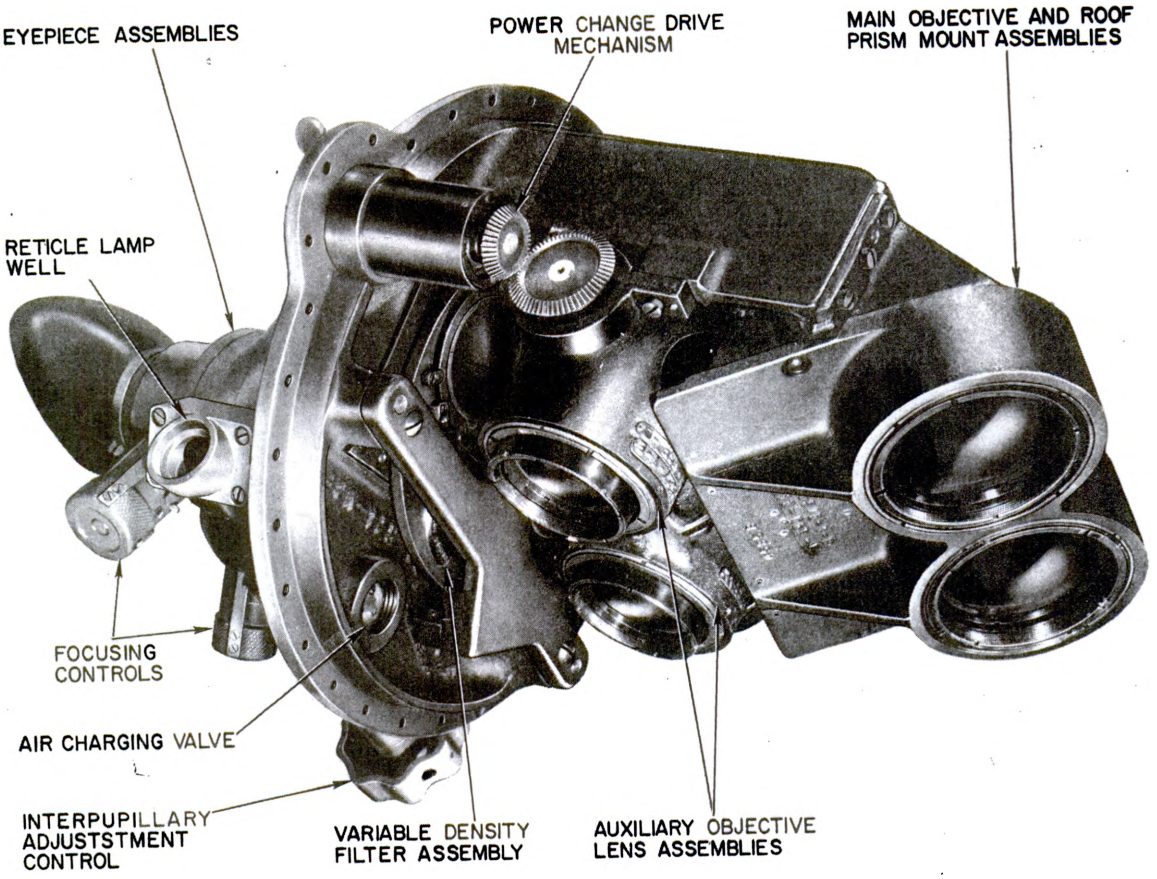
The entire telescope is pressure tight and pressurized with dry air or nitrogen at 4 pounds per square inch.

Telescope Mk 100 Mod 0 and Mk 100 Mod 1 are identical in physical appearance, basic construction, and operating characteristics. The difference between these telescopes is in the method used in shaft sealings. Mod 0 uses oil seals. Mod 1 uses O-rings.



148.424

Figure 3-10.—Telescope Mk 100 Mods 0 and 1, rear and right side view.


EYEPIECE ASSEMBLIES
POWER CHANGE DRIVE MECHANISM
MAIN OBJECTIVE AND ROOF PRISM MOUNT ASSEMBLIES
RETICLE LAMP WELL
FOCUSING CONTROLS
AIR CHARGING VALVE
INTERPUPILLARY ADJUSTSTMENT CONTROL
VARIABLE DENSITY FILTER ASSEMBLY
AUXILIARY OBJECTIVE LENS ASSEMBLIES

148.425

Figure 3-11.—Faceplate assembly.

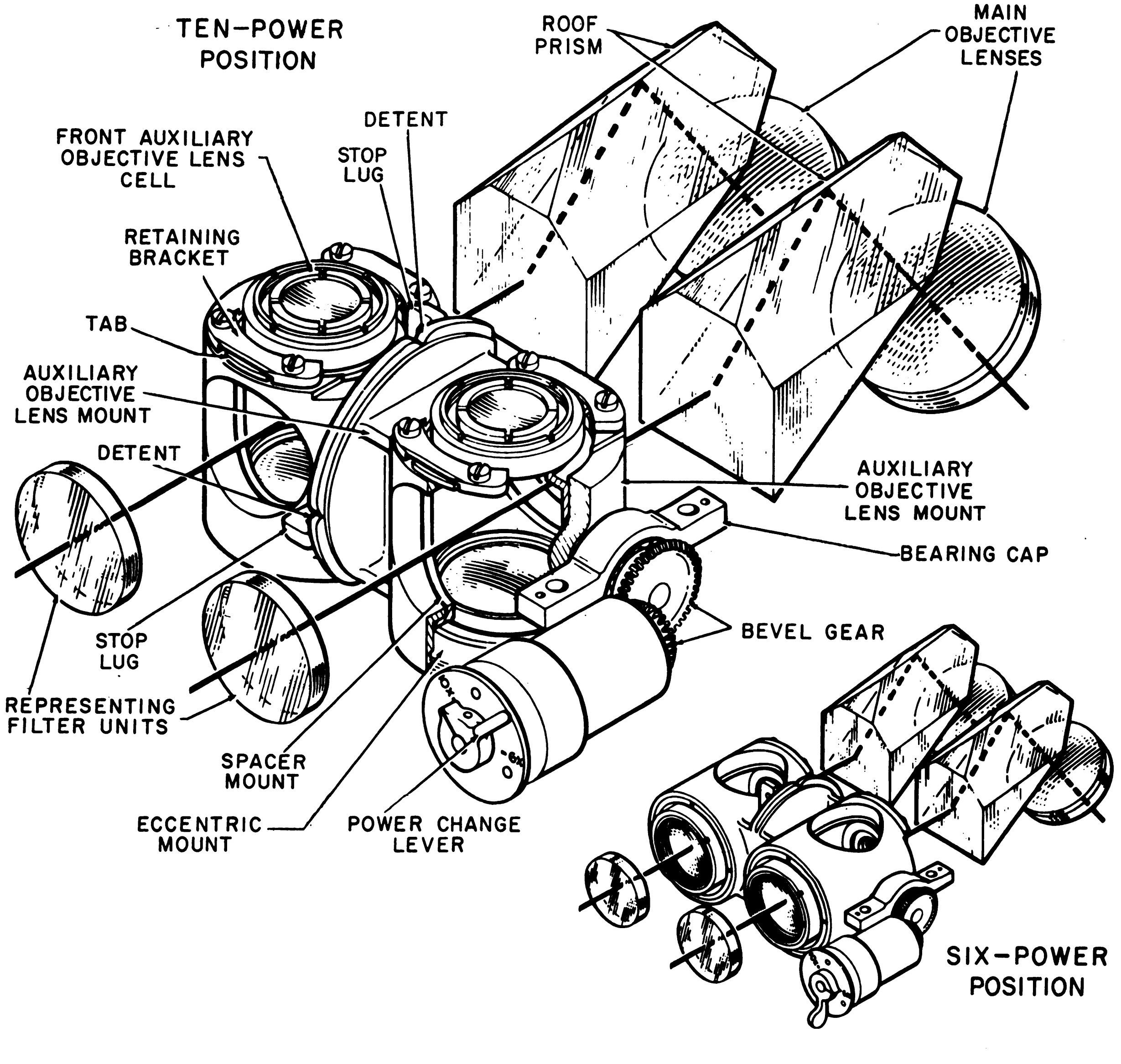
FACEPLATE ASSEMBLY.—The faceplate assembly contains all the optical components of a telescope except the objective mirror and window. Figure 3-11 shows the faceplate assembly removed from the telescope housing. The faceplate proper is a flat circular casting with a circumferential flange. This flange secures the faceplate to the body casting. A cast extension protrudes from the inner side of the faceplate. It supports the main objective and roof prism mounts and the auxiliary objective lens assembly. The variable density filter assembly is secured to the inner surface of the faceplate. The faceplate, pierced with two holes, permits passage of light into the eyepiece assemblies. The right eyepiece prism is mounted in a cavity in the faceplate casting. The left eyepiece prism, in a separate mount, is secured to the faceplate so that it can be rotated. Rotation of the left eyepiece prism mount varies the distance between eyepieces and provides for interpupillary adjustment. The eyepiece housing is secured to the prism mounts by flanges. On the exterior of the faceplate casting are the telescope operating controls, the air outlets, and the charging valve.

MAIN OBJECTIVE LENS MOUNT ASSEMBLY.—The main objective lens mount assembly consists of the main objective lenses and the roof prisms. Both systems are mounted in a single casting and are secured to the end of the faceplate extension. The roof prisms turn the optical axis through an angle required to place the objective lenses above the objective mirror. Prisms are secured by a retaining bar located over each prism. The alignments of the prisms is maintained by means of a button that is inserted in a hole through the retaining bar. The bar is held against the prisms by a pressure strip. Prism light shields are secured over the adjacent roofs of the two prisms.

The objective lenses are mounted in a lens cell that is threaded into the lens housing. The objective lens housing is a bronze casting forming two cylindrical sections in which the objective lenses are mounted. The objective lens housing, surrounded by an eccentric ring, is fitted into the objective mount and secured by the lock ring. The eccentric ring permits the adjustment of the lens during collimation.

AUXILIARY OBJECTIVE LENS ASSEMBLY.—The auxiliary objective lens system changes the magnification of the telescope to either ten or six power. The auxiliary objective lens assembly (figure 3-12) contains two identical lens systems, one for the right and one for the left optical system. Each of these systems is installed in a separate cylindrical mount. The two mounts are located alongside each other in a common casting. The assemblies are located in the optical systems between the variable density polarizing filter units and the roof prisms.

The lens systems are rotated by the power change shaft and lever, which extend through the faceplate alongside the right eyepiece prism housing. The shaft is sealed against leakage and is supported by two ball bearings. A bevel gear is mounted at the inner end of the shaft. This



148.426

Figure 3-12.—Auxiliary objective lens assembly.

bevel gear is in mesh with a mating bevel attached to a trunnion extending from the right auxiliary objective lens mount. A similar trunnion extends from the left mount. Ball bearings support both trunnions. Bearing housings, secured to the extension of the faceplate casting, support the entire assembly. The system is positioned in exact alignment by detents. The position of the lens is fixed when the detent is engaged by a detent roller. The roller is mounted on a spring that is secured to the faceplate extension. A stop arm (not illustrated) extends from the faceplate extension. Two stop lugs, one for each position, extend from the mount bracket. Fine adjustment of the stop position is accomplished by adjusting screws that extend through the stop lugs.

VARIABLE DENSITY FILTER ASSEMBLY.—The variable density filter assembly is mounted on the inside of the faceplate. It introduces variable density polarizing filters into both optical systems.

Each variable density filter unit consists of two polarizing plates. One plate is fixed in position on the objective side of the mount and the other is installed in a rotating mount. Rotating the mount aligns the two plates with each other. It also repositions the rotating plate to any position, between alignment and 90° out of alignment, to vary the density of the filter.

The variable density filter control knob projects from the faceplate above the headrest assembly. It controls the placement of filters in the optical assembly and changes the density settings of the filters. The filter knob shaft extends through the faceplate assembly and connects with the mount drive gear and filter drive gear.

The mount drive gear is slotted. A pin, extending from the filter drive gear, engages this slot. When the knob is rotated counterclockwise, the filter drive gear turns until its pin engages the end of the slot, causing the mount drive gear to turn. When the mount drive gear turns, the filter mounting plate is rotated to place the variable density filter units into the optical system. A detent roller engages at this position. At the same time, a rubber bumper secured to the back of the filter mount engages a stop lug on the filter mount bracket. This action sets the variable density filter units in the minimum density position. Turning the filter knob clockwise increases the density. When this knob is turned clockwise, the filter drive gear turns and its pin moves through the slot, allowing the mount drive gear to remain stationary. The filter drive gear causes the rotating polarizing plate to turn. The filter density increases as the filters approach alignment.

Clockwise rotation of the filter knob through 90° brings polarizing plates to the maximum density position. It also brings the pin of the filter drive gear against the opposite end of the slot in the mount drive gear. Continued rotation turns the mount drive gear clockwise. The filter mount rotates back to the other detent and the clear glass plates return to the optical system.

EYEPIECE ASSEMBLIES (LEFT AND RIGHT OPTICAL SYSTEMS).—The two eyepiece assemblies are identical. A retaining ring secures the eye lens against a shoulder that has been machined into the eyepiece body tube. The tube is sealed for airtightness with wax. The intermediate and field lenses are mounted in a draw tube, separated by a spacer, and secured by a retaining ring. Rotation of the focusing control knob moves the draw tube back and forth within the body.

The focusing control knob is pinned to the focusing shaft. A friction drag is provided by a helical spring that presses a friction plate against the oil seal retainer. A diopter scale, graduated in quarter diopters, is engraved on the focusing control knob.

Rotation of the focusing control knob is limited. A stop arm extends from the packing housing at the limits of rotation and bears against a stop screw.

The packing housing is threaded into the eyepiece housing and is seated against a wax seal. The packing housing provides a pressure-tight seal for the focusing shaft.

You control the position of the draw tube by rotating the focusing knob. This rotary motion of the focusing knob is changed to the linear motion required to focus the telescope. A pin in the end of the focusing shaft engages a hole in the center of an actuating plate. The actuating plate slides into a slot milled in the bottom of the draw tube normal to the axis of the draw tube.

EYEPIECE PRISM ASSEMBLY.—The two eyepiece prisms are identical but their mounting details are different. The left prism housing is a separate casting mounted in a circular opening in the faceplate. It is mounted so that it rotates about the base. The joint is secured against air leakage by an O-ring seal. The prism itself rests on four pads that are cast in the right-hand wall of the housing. During collimation, fine alignment of the prism is accomplished by scraping these pads. The vertical surface at the eyepiece end and the vertical surface at the opposite end of the prism bear against a prism retainer.

The lower surface of the prism is held against the bottom pads by a pressure screw. This screw passes through the prism housing and bears against a pressure block that is in contact with the top of the prism. A pressure plate, button, and spring on the left side of the prism hold the prism against the side pads.

The right-hand eyepiece prism housing is integral with the faceplate prism. This prism is secured in a prism mount. This mount is a bronze casting with four pads on the bottom and two pads on the left side. The bottom and left side of the prism bear against these pads, which were scraped for fine alignment of the prism. The bottom of the prism is held against the bottom pads by a pressure screw. The pressure screw passes through the top of the mount and bears against a pressure block that is in contact with the top of the prism. The left side of the prism is held against the side pads by a retaining spring. This spring presses against a button on a pressure plate that bears against the right side of the prism.

The vertical face of the prism and its eyepiece end bear against a diaphragm that is threaded into the reticle mount. The vertical face of the prism is held in this position by a prism retainer against its opposite face. The entire prism and mount are secured in the housing by a flange at the objective end of the mount.

RETICLE ILLUMINATION ASSEMBLY.—The reticle illumination system is attached to the right-hand eyepiece prism mount. Light from the reticle lamp is directed against the edge of the reticle by a prism, a window, and an orifice drilled through the eyepiece prism mount. This orifice is in alignment with a similar orifice in the reticle mount. The illuminator window is secured over the orifice by a retainer ring. The prism is cemented into a housing secured to the eyepiece prism housing by four screws and a gasket. The reticle lamp assembly is installed in a housing threaded into the illuminator prism housing.

Body Casting

The external cavity at the right of the body is the opening for the elevation drive mechanism. This cavity is made pressure-tight by a cover plate at the side, by a plug in the top opening, and by a stuffing box at the bottom opening. The elevation drive shaft passes through the bottom opening.

The body casting contains an access hole on the left side. It was provided to permit passage of an elevation output shaft for use with Camera Adapter Mk 1 Mod 0. Three small pads were also provided for its installation. Since this adapter is no longer provided with the telescope, the opening has been sealed by a pressure-tight cover.

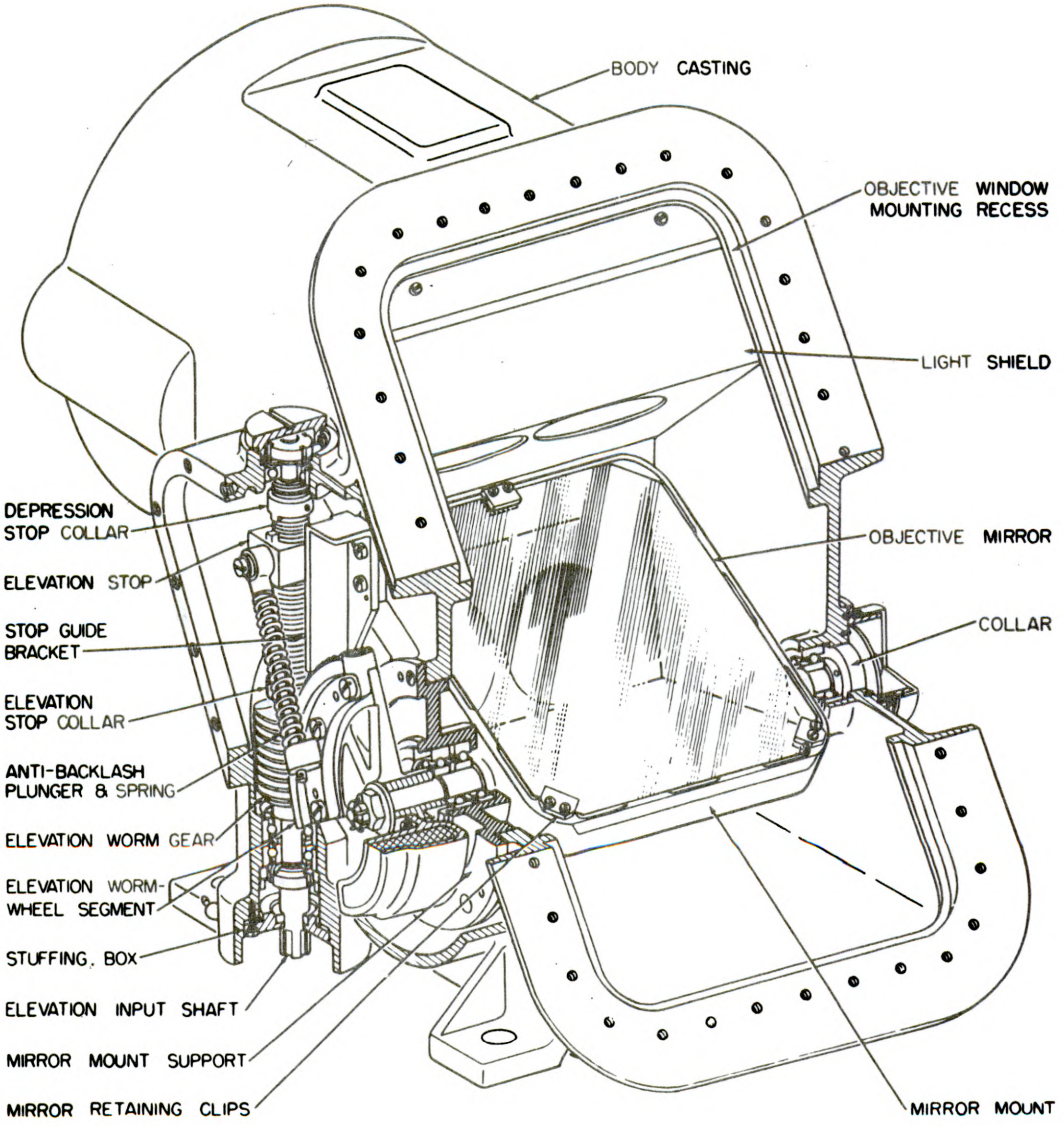
Air outlet valves are located in the left side of the body casting, in the elevation drive mechanism cover, and in the side of each eyepiece prism housing. The air charging valve is in the faceplate and is visible in figure 3-10.

OBJECTIVE WINDOW.—The objective window is the closure for the slanted rectangular opening in the front of the telescope. This window is recessed (figure 3-13) into the enclosure and is secured by a retaining ring. Gaskets both inside and outside of the window are compressed to form a pressure-tight closure.

LIGHT SHIELD.—The light shield (figure 3-13) separates the cavity into two parts; one contains the faceplate assembly, the other contains the mirror. The light shield is composed of two separate sheet metal pieces secured together by screws. This complete assembly is secured to lugs at the top and bottom of the body casting. The shield is pierced by two large circular holes through which light passes to enter the objective lenses.

OBJECTIVE MIRROR.—The objective mirror (figure 3-13) is in a mount that is movable in elevation. The position of the mirror provides a movable line of sight and is a source of elevation information for the fire control system.

ELEVATION DRIVE MECHANISM.—The elevation drive mechanism controls the position of the objective mirror. The objective mirror is positioned in elevation through a sector gear. The sector gear is driven by a worm gear mounted in the elevation mechanism housing (figure 3-13). The lower end of the worm shaft extends through a stuffing box and terminates with a spine connected to the elevation drive shafting of the gun director. The gear ratio provides for rotation of the mirror mount through one-half of the elevation input angle. The actual elevation of the line of sight is double the angle through which the mirror rotates because of multiplication by reflection.



148.427

Figure 3-13.—Body casting assembly, cutaway view.

An elevation stop mechanism is provided as part of the elevation drive mechanism. The stop mechanism is installed on the threaded section of the elevation input shaft above the worm gear. It consists of a traveling-nut stop and two stop collars.

Rotation of the traveling-nut stop is prevented by a guide bracket secured to the inner wall of the elevation mechanism cavity. When the telescope is depressed, the traveling-nut stop rides upward on the drive shaft; as the telescope is elevated, it rides downward.

The upper and lower stop collars are fixed in position on the elevation drive shaft. They restrict the telescope to operation between 30° depression and 100° elevation. These collars are secured to the elevation shaft by setscrews.

An antibacklash unit is provided to spring load the worm gear sector in one direction. An antibacklash spring is under compression and applies force to an eyebolt secured to the worm wheel. The spring is held by a rod that passes through its center and through the eyebolt. The rod is secured at the top to the traveling-nut stop.

The compression of the antibacklash spring and the force exerted on the worm wheel by the antibacklash spring are held constant through the range of elevation of the telescope.

MIRROR MOUNT.—The telescope objective mirror is mounted on a flat rectangular casting and is secured by three clips screwed to an edge of the casting (figure 3-13). The mirror mount is carried by two trunnions supported by ball bearings mounted in the body casting. The right trunnion extends beyond its bearing to form the base to which the elevation sector gear mount is keyed.

ELEVATION SECTOR GEAR MOUNT.—The mirror mount is driven by the elevation sector gear mount. A worm gear segment is located on the sector gear mount to engage the elevation worm gear. The resulting assembly is balanced by addition of a weight to the elevation sector gear.

Optical System

For you to observe and track both surface and aircraft targets, the telescope line of sight must be capable of two motions—traverse and elevation. Elevation motion is obtained by rotation of the objective mirror. Traverse motion is obtained by training the entire director. Traverse motion (figure 3-6) lies in a slant plane. Elevation motion lies in a vertical plane (figure 3-7).

To ensure elevation and traverse motions lie in the required planes, you must take extreme care to align the telescope and its elements. To assure accurate alignment, you must carefully machine the basic reference surfaces on the telescope case. The optical systems and elevation mirror are aligned to these machined surfaces.

You establish the horizontal reference plane by machining the bottoms of the four telescope mounting pads. You establish the vertical reference plane by machining the left edges of the two left-hand mounting pads.

During assembly, the elevation mirror is positioned at zero elevation. The two optical systems of the telescope are aligned with their lines of sight parallel to each other and parallel to both reference planes. The trunnions of the mirror are positioned so that the mirror axis of rotation is parallel to the vertical and horizontal planes. The telescope is a binocular instrument. It contains two complete optical systems. Except for the reticle, which is in the right optical system only, these systems are identical. Since the objective window and the objective mirror are large enough to include both systems, they are common to both.

The components of the optical systems, shown in figure 3-14, are discussed in the following paragraphs.

OBJECTIVE MIRROR.—The objective mirror is of a borosilicate crown glass. It has a polished front, reflecting surface and is coated with evaporated aluminum over a chromium undercoat. This mirror reflects light rays and changes the elevation line-of-sight axis.

MAIN OBJECTIVE LENSES.—Each main objective lens is a doublet, consisting of a barium crown glass convex lens and a dense flint glass concavo-convex lens. As rays of light enter the optical system, the lenses converge these rays and focus them in the plane of the reticle; thus, a real image is formed at the reticle. When the light rays pass through the main objective lenses, the image is inverted. However, as the light rays pass through the next component, the roof prism, the image is inverted again; the reticle then receives a correct image.

ROOF PRISMS.—The roof are of borosilicate crown glass. The roof of each prism comprises two reflecting surfaces at 90° to each other. The bottom reflecting surface of each prism is normal to the entering path of light. The roof prism inverts the target produced by the objective lenses. It then diverts the path of light through a 55° angle in a vertical plane so that it exits from the prism horizontally.

AUXILIARY OBJECTIVE LENS GROUP.—Each auxiliary objective lens group consists of two parts. The front part is a doublet consisting of a concave lens of borosilicate crown glass and a concave-convex lens of extradense flint glass. The rear consists of a doublet and a singlet. The rear doublet consists of a convex lens of dense barium crown glass and a concave lens of extradense flint glass. The singlet immediately in front of the doublet consists of a convex lens of barium crown glass.

The auxiliary objective lens group is mounted so that it can be rotated as a unit either into or out of the optical system. When used, it functions as a reducing system. It changes the magnification from ten times to six and increases the field of view.

VARIABLE DENSITY FILTERS.—Each optical system contains a variable density filter unit mounted in a single assembly. Each unit consists of two polarizing filter plates superimposed on each other. One plate is fixed in position with its axis oriented to minimize glare and surface reflections. The other plate is rotatable; its axis may be positioned at any point between parallel to and 90° from the axis of the other plate. The parallel position is for minimum density; the 90° position for maximum density. When the variable density filters are positioned out of the system, clear glass plates in the filter assembly are inserted automatically. These glass plates have the same optical characteristics as the filters. Their function is to prevent any disturbance of the optical system.

RHOMBOID PRISMS.—The rhomboid prisms, one in each optical system, are constant deviation prisms made of barium crown glass. They deviate the optical lines 44.45 millimeters downward so that they are in coincidence with the horizontal axes of the eyepieces. Each prism and eyepiece composes a single assembly. The left assembly can be rotated to correct the spacing between the two eyepieces, permitting adjustment to the interpupillary distance of the individual operator.

RETICLE.—Only the right optical system contains the reticle, which is between the rhomboid prism and the eyepiece. It is a plano-parallel disc of borosilicate crown glass mounted with its front surface at the focal plane of the objective. The reticle pattern etched into this surface is shown in figure 3-14. The left optical system contains a sealing plate that is identical to the reticle plate except it does not have a reticle pattern etched on it. It is located in a position comparable to the reticle plate but in the left optical system.

RETICLE ILLUMINATION SYSTEM.—Under conditions of low visibility, the reticle pattern may be illuminated by light from a six-volt lamp. The light is transmitted through a small constant deviation prism and an illuminator window to a channel in the reticle mount that terminates at the edge of the reticle plate. A separately mounted rheostat permits variation of the intensity of illumination.

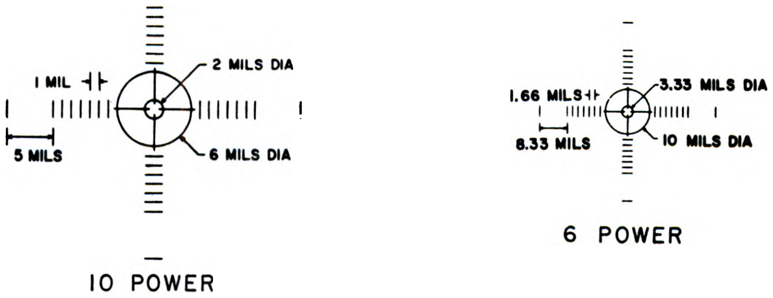
EYEPIECES.—Each eyepiece consists of three lenses: a field lens, an intermediate lens, and an eye lens. The field lens is a triplet. It consists of a concavo-convex lens of barium crown glass, a concave lens of extradense flint glass, and a convex lens of barium crown glass. The intermediate lens, a doublet, consists of a concavo-convex lens of extradense flint glass and a convex lens of dense barium crown glass. The eye lens is a plano-convex lens of dense barium crown glass. Combined, these eyepiece lenses magnify the true field and produce collimated light rays issuing from the exit pupil. Each pair of field and intermediate lenses is mounted in a draw tube, which permits the limits of + 1 and − 2 diopters.

OPTICAL SHOP MAINTENANCE

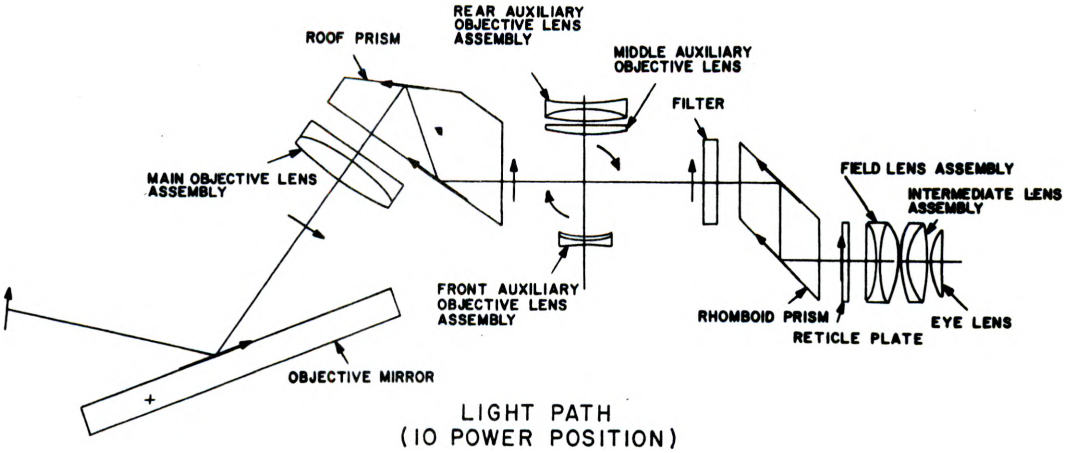
Overhaul of a telescope must be approached systematically. You must thoroughly inspect the equipment and document the findings. The findings should be used to plan the overhaul procedures. You should disassemble parts only to the extent necessary to effect repairs.

Initial Inspection

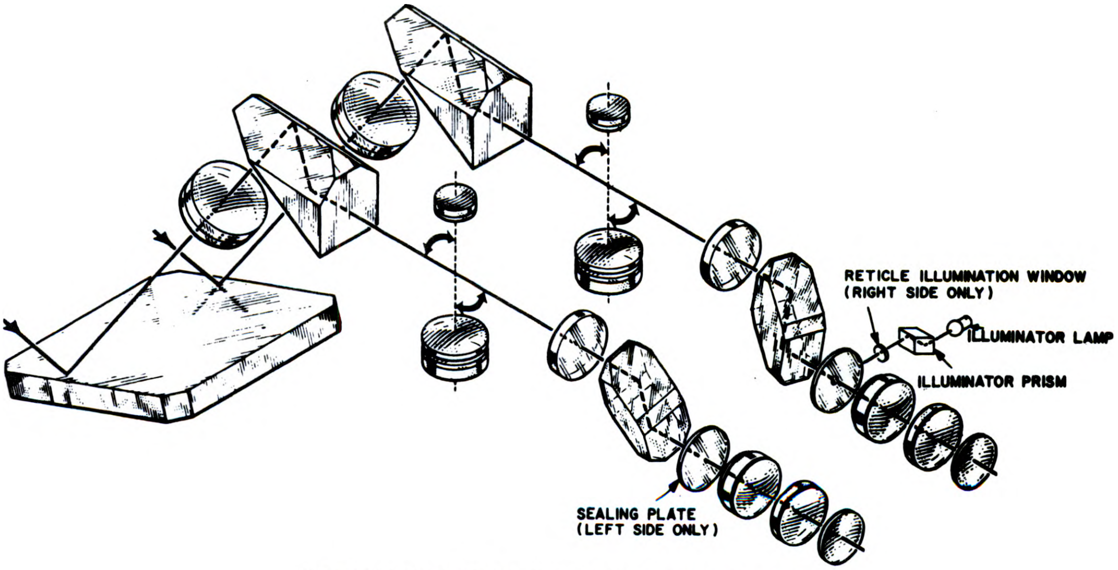
Immediately upon receipt of a telescope at an optical repair shop, inspect the telescope and note all defects on a master work sheet. Other defects discovered later and all repairs made during overhaul should be added to the master work sheet. This work sheet provides a cumulative



RETICLE PATTERNS


REAR AUXILIARY OBJECTIVE LENS ASSEMBLY
ROOF PRISM
MIDDLE AUXILIARY OBJECTIVE LENS
FILTER
MAIN OBJECTIVE LENS ASSEMBLY
FIELD LENS ASSEMBLY
INTERMEDIATE LENS ASSEMBLY
FRONT AUXILIARY OBJECTIVE LENS ASSEMBLY
RHOMBOID PRISM
RETICLE PLATE
EYE LENS
OBJECTIVE MIRROR

LIGHT PATH
(10 POWER POSITION)


RETICLE ILLUMINATION WINDOW (RIGHT SIDE ONLY)
ILLUMINATOR LAMP
ILLUMINATOR PRISM
SEALING PLATE (LEFT SIDE ONLY)

ARRANGEMENT OF OPTICAL COMPONENTS
(10 POWER POSITION)

148.428

Figure 3-14.—Optical system elements.

record of all defects found in and repairs done on the telescope.

Include in the initial inspection all mechanical and working parts and all limit stops and detents. Inspect all seals and gaskets for tightness and deterioration. Check the telescope carefully for corrosion, cleanliness, the condition of its paint, index marks, and scales.

Inspect the optical system for parallax, image distortion, separation of lenses, and fogging. Perform a preliminary collimation to determine the alignment of the optical systems. While a telescope is awaiting overhaul in the optical repair shop, provide it with the same stowage precautions and treatment as given new and overhauled instruments.

Physical Damage Inspection

To determine physical damage, first examine for internal cleanliness by looking into the telescope in bright light at a uniform field having average daylight brightness. Repeat this examination by looking through the telescope from the objective end. For a broader field of view, use an auxiliary lens placed behind the eyepiece.

No stray or scattered light or reflections from surfaces within the telescope should be visible in the field of view. Stray or scattered light should not enter the exit pupil or be visible in the vicinity of the exit pupil when the pupil is viewed from a distance of two or three feet along the extended ocular axis. All internal surfaces from which stray or scattered light might be reflected must be threaded, knurled, grooved, or scored to eliminate reflection. Do not use paint, enamel, lacquer or any other material that might flake from the interior surfaces of the telescope.

Manipulate all operating controls through their ranges to determine that the operation of the telescope is positive, accurate, free from excessive friction, and will not transmit shock or jar to optical elements. During this examination, make sure that the operation of the controls can be conducted with gloved hands.

Inspect the reflection reducing film coated surfaces for damage to the film coating. Check the external metal surfaces for signs of corrosion, rust, chipped paint, or deterioration. Make sure that all external metal surfaces, except mounting surfaces, have two coats of light gray enamel and that all operating knobs, handles, and so forth, are coated with a durable black, baked lacquer.

Optical System Inspection

Use a star test to check the image for points, flare, rays, fog, haze, and halos (other than normal diffraction rings). Use this test to also check for differences in coloration between sides of the star. A slightly defocused image should remain round. The ocular setting between three stars must not exceed 0.2 diopter.

The limits of resolution at any point within 1° of true field from the field center for parallel lines of any orientation must be

1. six seconds or better for magnification of 10 diameters and
2. ten seconds or better for a magnification of 6 diameters.

Each eyepiece of the telescope must be capable of being focused from +1 to −2 diopter when you rotate a ring or knob that moves an internal lens component. Each line of the focusing scale must be correctly located within 0.25 diopter, and each interval should be correct within 0.25 diopter. The eyepieces must be airtight.

Disassembly

Disassemble the telescope systematically. Thoroughly inspect the telescope prior to overhaul to determine the degree of disassembly necessary. Avoid needless disassembly.

CAUTION: Handle the objective mirror very carefully. It is a front-surface-coated mirror, and its coating can be easily damaged. Remember, prior to disassembly internal nitrogen pressure must be bled off to prevent injury to repairmen.

SEPARATION OF BODY AND FACEPLATE CASTINGS.—Remove the securing screws from the periphery of the faceplate. Work the faceplate free of the body casting following the axis of the locating dowel pins. Place the faceplate assembly on a workbench. Be sure to protect the mounting surfaces and exposed parts from damage.

BODY CASTING DISASSEMBLY.—The objective window, the light shield, the elevation drive mechanism, and the objective mirror assembly can be disassembled from the body casting. The elevation drive mechanism must be disassembled and removed from the body before the objective mirror mount can be disassembled. During all disassembly operations, take extreme care to protect the objective mirror from dust and shock.

Remove the objective window before any further disassembly is attempted so that the objective mirror can be provided necessary protection.

Although the removal of the light shield may not be necessary, its removal will allow more clearance for removing the objective mirror. Before proceeding, cover the objective mirror with lens paper and a sponge rubber pad to protect it.

To remove and disassemble the elevation drive mechanism, place the body casting on the work surface. Be sure to have at least twelve inches of clearance directly under the elevating worm shaft.

FACEPLATE DISASSEMBLY.—To disassemble a faceplate, you must first remove the objective mount assembly. You then remove the roof prisms and finally the auxiliary objective lens assembly.

Normally, disassembly of the auxiliary system mounts will not be necessary. If one of the three auxiliary lenses must be replaced or cleaned, be sure to mark the orientation of the eccentric rings and the lenses as they are removed. You will use these marks for reference during reassembly.

Before removing the variable density filter assembly from the faceplate, turn the filter control knob to its extreme counterclockwise position. Then rotate the polarizing filter units to the minimum density setting. Indicate, by a scribe mark, the position of mesh between the filter drive idler and the filter drive pinion.

The housing in which the right eyepiece prism is mounted is an integral part of the faceplate. The assembled prism and mount should be removed from the inner side of the faceplate.

The left eyepiece prism housing is mounted in the faceplate so that it may be rotated. You can remove it as a unit from the faceplate by removing the prism housing retainer.

The left and right eyepiece assemblies (figures 3-14) are identical. They are dismounted from the faceplate assembly by removing the screws that secure the eyepiece assembly prism housing.

Reassembly Procedure

Reassembly of the telescope is the reverse of disassembly. Be sure to check and match the bench marks you made during disassembly for proper orientation and fittings of components. For the selection of proper lubricants and the procedure for application, refer to OP 3750, chapter 6, and MIL-G-23827.

The optical system must be adjusted with its components assembled on the faceplate but not yet installed in the body casting. First, adjust the main optical systems to be free of parallax and to be parallel with each other so that their optical axes are perpendicular to the faceplate flange. Next set zero diopters. Check for parallax with the auxiliary objective in the line of sight.

When parallax has been removed, check the magnification with a dynameter. Install the faceplate assembly in the telescope body. Set the objective mirror at 0° elevation using the index marks on the mirror mount and the body casting.

Check the accuracy of the elevation drive mechanism by elevating it from 0° to 25°. Exactly five turns of the handwheel should bring the crossline intersection into coincidence with that of the 25° Collimator Telescope Mk 8 Mod 1. Telescope Mk 100 must be elevated from 0° to 90°. Exactly 18 turns of the handwheel should bring the crosslines into coincidence at the 90° position.

Complete procedures for overhaul, collimation, and sealing/drying of the Mk 100 telescope are found in OP 3693.

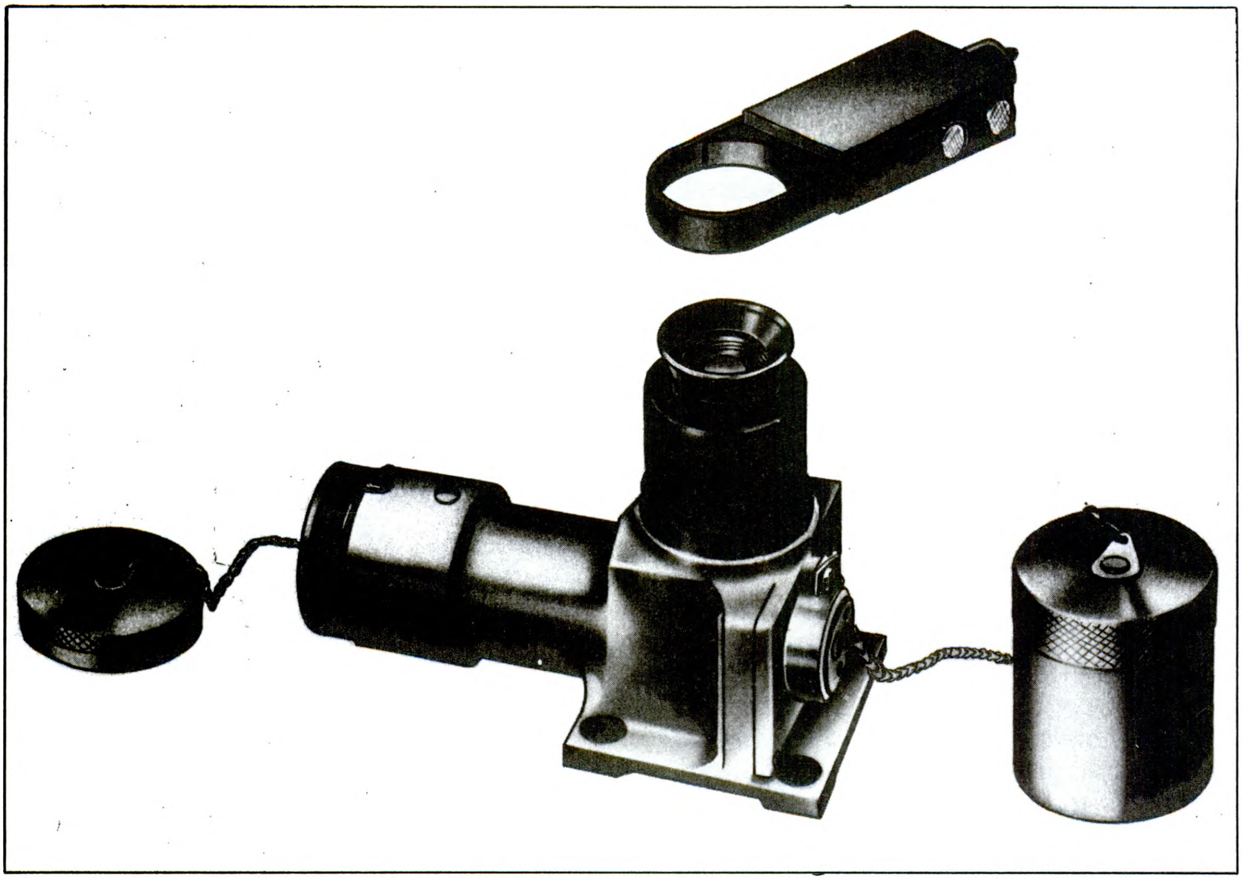


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Figure 3-15.—Mk 104.

MK 104 MOD 0 AND 1

Telescope Mk 104 (figure 3-15) is used to boresight Radar Set AN/SPW-2, Radar Set AN/SPG-51, and Gun Fire Control System Mk 56. This telescope is mounted on the radar antenna mount and aligned with the axes of motion.

This telescope internally focuses at all ranges from 15 feet to infinity with magnification of approximately 8 power with a 6°-0′ field. A range focus control and a reticle with two coordinates graduated in mils are contained in the eyepiece, which is 90° from the line of sight. The instrument is sealed internally and charged with dry nitrogen.

Telescope Mk 104 Mod 0 and Mk 104 Mod 1 are identical except for a reticle illumination lamp that is provided with a Mk 104 Mod 1.

The optical characteristics of the Mk 104 Mod 0 and Mod 1 are listed below.

True field	6°
Exit pupil	3.6mm
Magnification	8x
Eye distance	15.3mm
Target Range	15 ft to infinity

The body of the Mk 104 telescope is a bronze casting of general cylindrical section in the form of a right angle (figure 3-16). Four pads on the bottom flange provide for mounting the telescope with four bolts, one through each pad. Two holes, 90° apart, are provided in the objective end of the body. One is used for an air outlet screw and the other for a screw to secure the cover chain clamp. A hole in the eyepiece end of the body is provided for another air outlet screw. This hole may vary in location from the one shown in figure 3-16 to 90° clockwise. On Mod 1 telescope

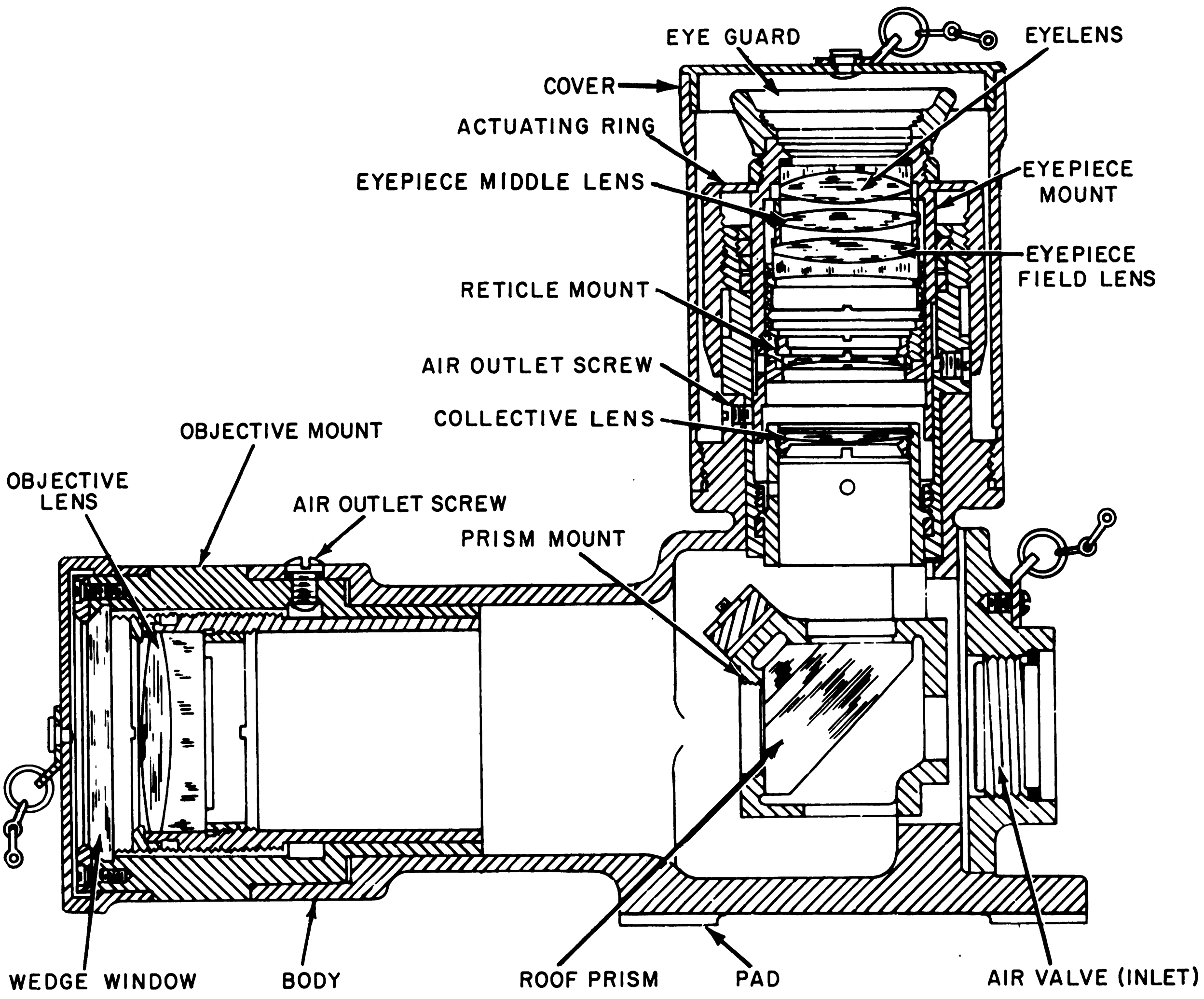


Figure 3-16.—Telescope Mk 104 internal arrangement.

only, a window is mounted for reticle illumination 45° from the air outlet screw hole. A rectangular opening at the rear of the body provides access to the prism mount. This opening is sealed by a cover plate that contains the air inlet valve. The internal surfaces of both the objective and eyepiece ends of the body contain seats for the objective mount and eyepiece insert bonded in place at assembly. Interior surfaces of the body are chemically darkened to reduce stray light reflection.

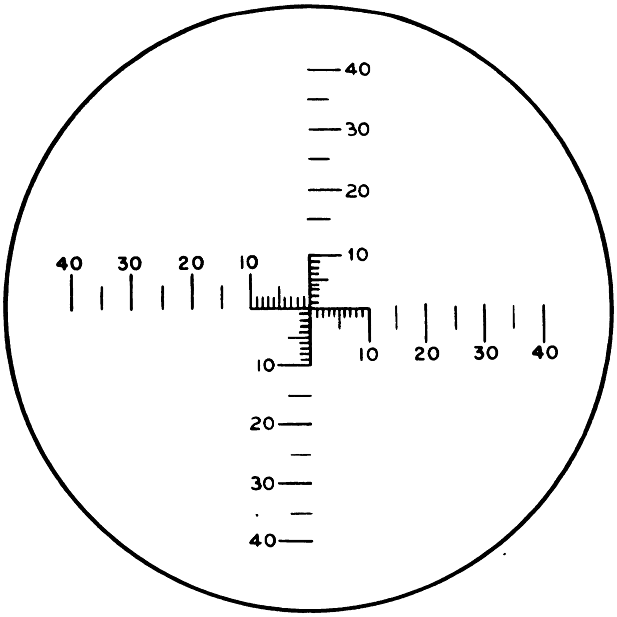
Optical System of the Mk 104 Telescope

The optical system of the Mk 104 telescope consists of the objective window, lens, and mount. The objective window is mounted in the front end of the objective mount and is held in place by a window retainer and gland. The joint between the window retainer and objective mount is sealed with sealant. The doublet objective lens is mounted in the lens cell and secured by a lens retainer. The lens cell threads into the objective mount and is locked in place by a lens cell lockring. Lateral saw cuts in the lens retainer and grooves in the lens cell provide an air passage to the inside of the objective window and to the air outlet screw. The inside surfaces of the lens cell and of the lens retainer are threaded to prevent reflection of stray light.

PRISM.—The right angle roof prism is mounted in the prism mount and is secured in place by two clamps and a clamp plate. Cork pads are inserted between the prism and clamps. Pressure to hold the prism is exerted by two setscrews through the clamp plate; the setscrews are locked in position by locknuts. The prism mount is a box-like bronze casting or brazement with a projecting flange for mounting the prism in the telescope body.

COLLECTIVE LENS.—The collective lens is mounted in the lens mount and secured by a lockring. The lens mount is held in place in the eyepiece insert by a spacer and lockring. The lens mount is provided with four holes for the passage of drying air.

RETICLE LENS.—The reticle lens is mounted in the reticle mount and secured by a lockring. The reticle mount is screwed into the eyepiece mount in focus with the eyepiece at a fixed setting of −0.9 to ±0.4 diopter. The reticle axis is collimated concentric with the mechanical axis to 2 arc minutes (Mod 0) ±30 arc seconds (Mod 1). It is squared with respect to the mounting pad within ±15 arc minutes. The reticle lens pattern is shown in figure 3-17. The crosslines are graduated from zero, at the point of intersection, to 40 mil at each end. The crosslines are graduated every mil up to 10 mils, then every 5 mils up to 40 mils.



148.431

Figure 3-17.—Telescope Mk 104 reticle pattern.

EYEPIECE LENSES, FOCUSING MOUNT, AND ACTUATING RING.—The eyepiece field lens, the eyepiece middle lens, and the eye lens are contained in the eyepiece mount. The eyepiece mount is a sliding fit in the eyepiece insert. The insert is bonded into the end of the telescope body at assembly. Spacers separate the field lens, middle lens, and the eye lens. The eye lens is sealed with sealant. Lenses and spacers are secured in the eyepiece mount by a lockring. Longitudinal grooves cut on the inside of the eyepiece mount and holes drilled in the spacers provide access for dry air to all lens surfaces. A threaded pin in the eyepiece insert rides in a longitudinal groove in the eyepiece mount to limit movement and prevent rotation of the eyepiece when you are focusing. The sliding joint between the eyepiece mount and the eyepiece insert is packed at the outer end to prevent leakage of air. The packing consists of two rubber gaskets, a spacer, and a gland. The packing is locked in place by two lockrings. Mod 1 telescopes incorporate O-ring seals instead of the packing arrangement. A plastic-type eye guard is screwed to the eyepiece mount. The inner surface of the eye guard is corrugated to prevent reflection.

The knurled actuating ring threads onto the eyepiece insert. The upper end of the actuating ring contacts a shoulder of the eyepiece mount and is retained by a locknut. On some early Mod 0 telescopes, a scale is secured to the lower end of the actuating ring by two setscrews. The scale has two graduations, marked INF and 15 FT, on its outer circumference 270° apart. A line engraved on the eyepiece insert serves as the index against which the scale on the actuating ring is read while you are focusing.

LAMPHOLDER AND PENLIGHT.—On the Mod 1 telescope only, a flat aluminum alloy block is machined at one end to fit the cylindrical section of the eyepiece end of the body casting. It is bored out along its length to accept a two cell (AAA size) penlight. A matching U-clamp (aluminum strap) fits around the body casting and retains the lamp holder that is secured by two thumbscrews. The penlight is held in the holder by a thumbscrew. A pushbutton switch on the end of the penlight is pressed to illuminate the reticle.

Preoverhaul Inspection

Upon receipt of the Mk 104 telescope for overhaul, perform the necessary inspection checks. If the telescope fails to satisfy any requirement (except exterior visual inspection), overhaul the unit. Evaluate any failure of visual examination; if the defect cannot be corrected by careful touchup or rework of the assembled telescope, overhaul the unit. If the telescope passes inspection checks, check telescope alignment and optical qualities for quality assurance. If the telescope fails to satisfy any one of the examination requirements, overhaul the unit.

Prior to disassembly and overhaul of the telescope, perform the necessary checks to determine the condition of the unit. To completely overhaul a telescope that satisfactorily passes a preoverhaul inspection is neither practical nor economical.

Disassembly Procedure

Disassemble the telescope only to the extent necessary to effect repair. Refer to the exploded views in chapter 5 of NAVSEA OP 3122 during disassembly.

INSPECTION OF PARTS.—Discard all gaskets, seals, O-rings, and penlight batteries (Mod 1 only). Refinish and clean all remaining parts. After cleaning, examine all metal parts for corrosion, condition of finish, and evidence of damage or excessive wear. Examine optical elements for the condition of the surfaces and edges and for evidence of separation of the doublet lens.

OPTICAL COATING EXAMINATION.—A visual inspection of the coating must be made to determine the quality of coating. Use a white fluorescent lamp and position it so that the lens and the optical coating comparison standard D7680600 reflect the image of the fluorescent tube. Compare the lens to each of the lenses in the standard acceptable range. A variance of color over the coated area is permissible. When white light strikes the coated surface at any angle of incidence from 0° to 30°, the rays must reflect a specific color from the coated surface. They must appear yellow-red from a film having the minimum permissible optical thickness (0.25 wavelength of 450 millimicrons) and purple-blue from a film having the maximum permissible optical thickness (0.25 wavelength of 600 millimicrons). Any lens not within tolerance should be replaced.

Reassembly Procedure

Reassembly of the telescope is the reverse of disassembly. When reassembling the Mk 104 telescope, check and match bench marks made during disassembly for proper orientation and fitting of the components. Put the prism cover on temporarily to keep the lint and dust out until completion of collimation.

To collimate the Mk 104 telescope and zero diopters, sequence the reticle, and adjust the objective focus at infinity. Align with 1 mil, the vertical and horizontal optical axes of the prism parallel to the Mk 104 telescope. Superimpose the vertical axis by using the wedge window and the horizontal axis by scraping the mounting pads. Follow the complete procedures for overhaul, collimation, and sealing/drying of the Mk 104 telescope found in OP 3122.

MK 102 MODS 2, 3, AND 4 GUNSIGHT TELESCOPES

The Mark 102 Mods 2, 3, and 4 gunsight telescopes are used on 5″/54 gunmounts Mk 42 and associated fire control systems (figure 3-18).

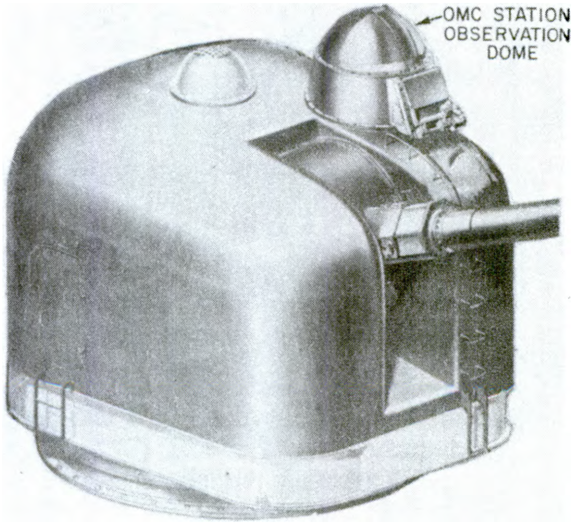


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Figure 3-18.—Gun mount.

The gun is normally operated by remote control with the gun fire control system. However, you must often control the gun movement locally. Figure 3-19 shows the arrangement of the one-man control (OMC) and the location of the Mk 102 telescope.

The telescopes used at the right and left local control stations are identical. Each telescope is fixed in position on the gun mount or director and is trained with it. Since it is used with a disturbed-line-of-sight system, the train position it will take is that of the gun line. To put the telescope on the tracking line so that the target can be followed, apply sight deflection to move the telescope line of sight back from the gun line. This is done by means of a servo system and rotating prism that optically move the line of sight in traverse through the correct angle as transmitted by the fire control system. The limits of line-of-sight movement in traverse are from −30° to +30°.

The telescope mount is fixed in elevation and does not elevate with the gun. The line of sight is elevated optically by a servo system similar to that used for sight deflection. The signal used is target elevation received from the fire control system. It is obtained by subtracting sight angle from gun elevation. Thus, the telescope line of sight is placed on the tracking line in elevation. The limits of line-of-sight movements in elevation are −20° to +85°.

The sighting component of Telescope Mk 102 types is a monocular telescope having a magnification of 8 diameters and a true field of approximately 8°. It contains a reticle having two concentric circles, one of 3 mils and the other of 15 mils true field diameter. The eyepiece is an internal focusing type, permitting adjustments to suit the individual eye from 1 to −3 diopter. The sighting portion of the unit is assembled in a gas-tight optical chamber. Valves are provided for

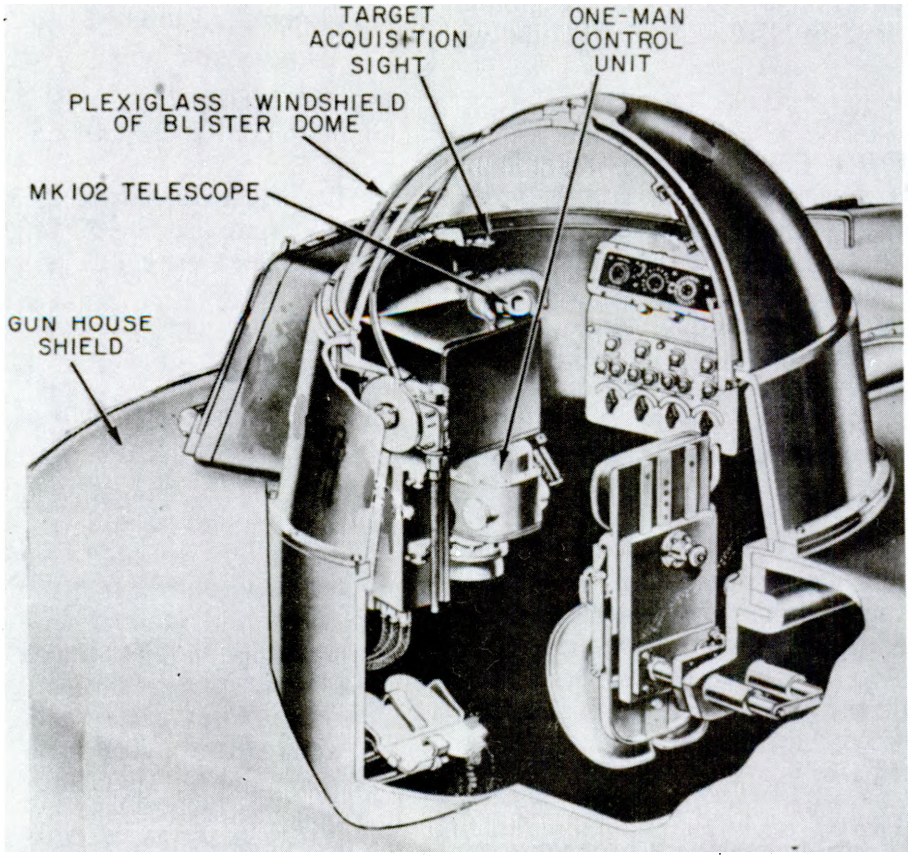

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Figure 3-19.—OMC.

charging with gas. The optical tube and eyepiece are inclined at an angle of about 20° to permit easy viewing.

The rest of the telescope housing is of watertight construction. It contains the rotating optical elements, their associated gear trains, the servo motor, and the synchro units.

The following controls and adjustments are provided for use by the observer:

Focus control knob—To adjust eyepiece diopter setting

Filter control knob—To use variable density polarizing filter

Reticle illumination control knob—To vary reticle illumination as needed

Headrest control knob—To adjust headrest position to suit observer

Stowed on the inside of the rear cover plate is an autocollimating mirror used to check alignment of the telescope. A synchro adjusting wrench is stowed in the servo chamber.

Modification Differences

Telescope Mk 102 Mods 2 and 4 are identical except for certain features of sealing at the rear cover plate and at the access plates to the servo chamber and a slight difference in the illumination window and the retainer ring for that window. All of these changes were made to improve the watertight integrity of the servo chamber and the gas-tightness of the optical chamber.

Telescope Mk 102 Mod 3 is interchangeable with Mods 2 and 4, but it contains many different features of construction. Comparison of these models, as shown in figure 3-20, will reveal considerable differences in the telescope housing and optical chamber, although the mounting surfaces and dimensions are identical. The most apparent interior difference appears in the optical components inside the optical chambers. Mod 3 uses a prism; Mods 2 and 4 use elevation mirrors. The traverse prisms are similar but accomplish their reflection in opposite directions because different means are used to direct the line of sight into the telescope chamber. Mods 2 and 4 employ a skew penta prism for this purpose, while Mod 3 uses a porro prism and a simple penta prism.

The telescope optics differ also. Mods 2 and 4 have a simple achromatic doublet objective lens, while Mod 3 has a compound telephoto objective lens. A slight difference also appears in the eyepiece optics as well as in the illumination systems. A special aspheric lens is used for the reticle. Study of figures 3-21 and 3-22 will show these major differences. Of course, differences in hardware, mounting, and so forth appear throughout; but these have no effect on the functional operation of the telescope.

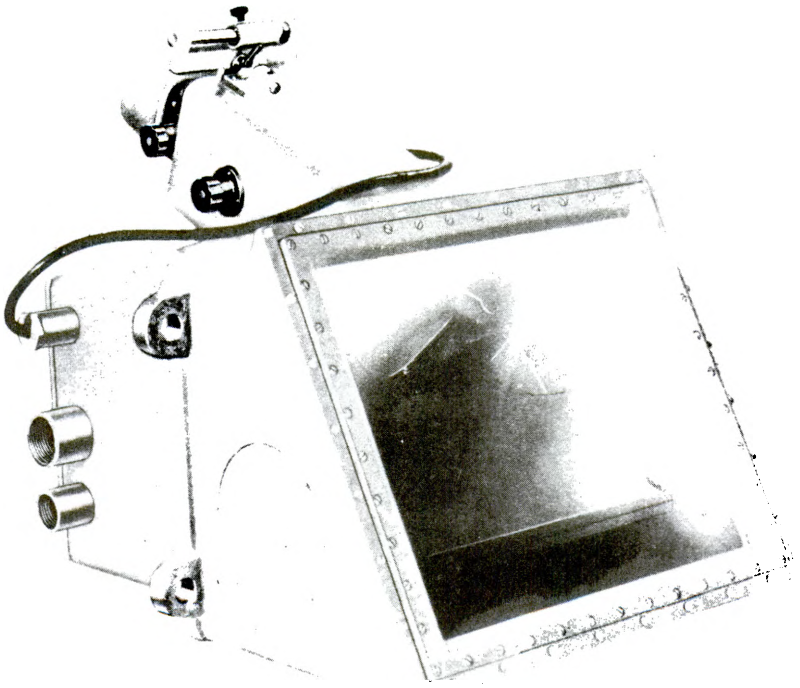
Optical System for Mods 2 and 4

The optical system of Telescope Mk 102 Mods 2 and 4 offers an unobstructed field of view of 8°—4° about a tracking line that may be moved to the limits of 85° above and 20° below the horizontal (zero elevation) reference plane and 30° to the left and right of a line perpendicular to the vertical reference plane.

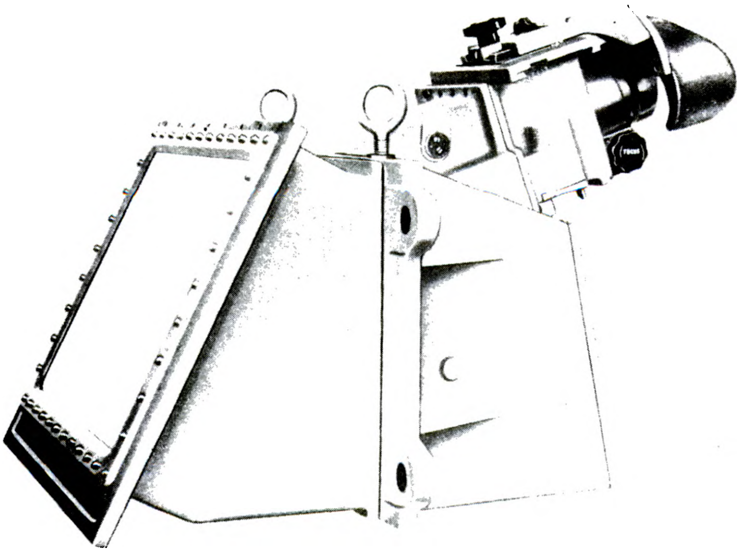
The optical system, figure 3-21, is identical for Mods 2 and 4 and consists of the following optical elements: window, elevation mirror, traverse prism, skew penta prism, objective lens, polarizing filters and compensating plate, reticle field lens, intermediate lens, and eye lens.

WINDOW.—The window is housed in the forward end of the telescope case. It transmits light to the rest of the optical system and, together with the case, protects the optical chamber from dirt, moisture, and physical damage. The window glass is optical quality and is rectangular in shape. The unexposed surface is treated with magnesium fluoride antireflection coating to increase light transmission.

ELEVATION MIRROR.—The elevation mirror is housed in the elevation assembly, which is located just inside the window



TELESCOPE
MK 102 MOD 2



TELESCOPE
MK 102 MOD 3

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Figure 3-20.—Telescope Mk 102 Mods 2 and 3, and amplifier Mk 91 Mods 1 and 2.

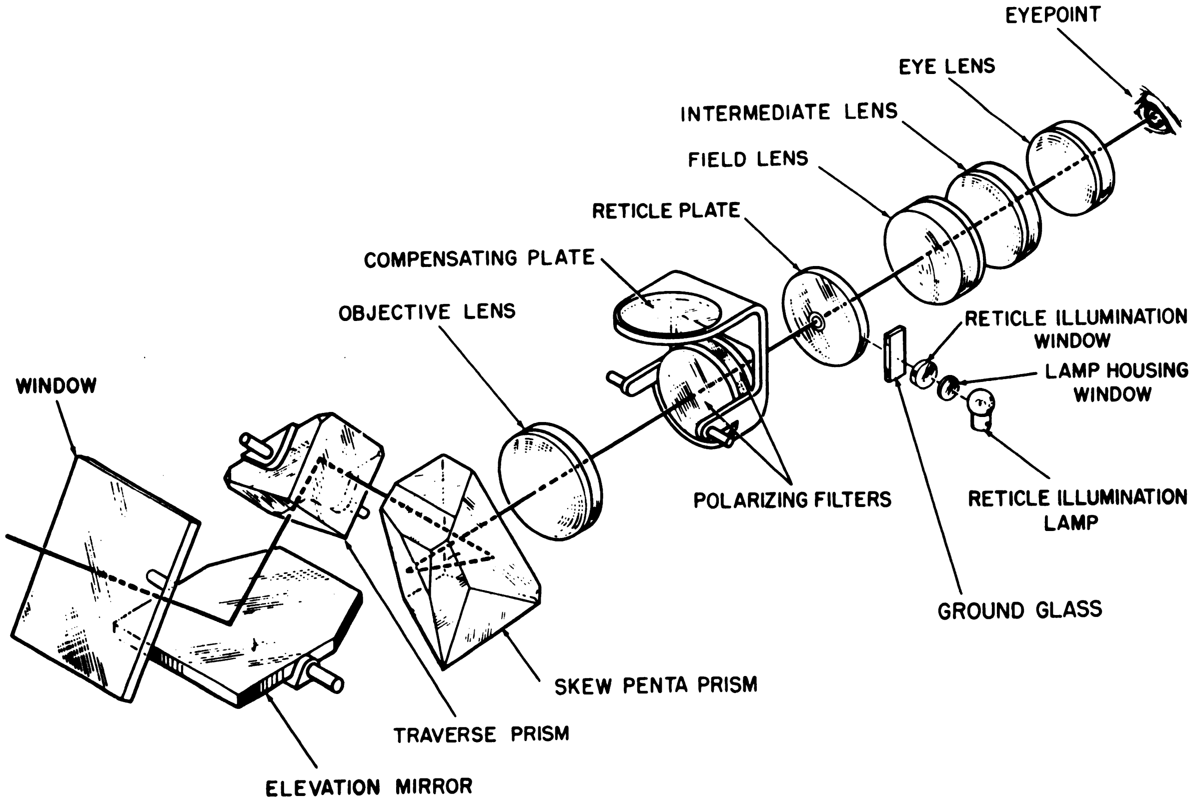

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Figure 3-21.—Telescope Mk 102 Mods 2 and 4; optical diagram.

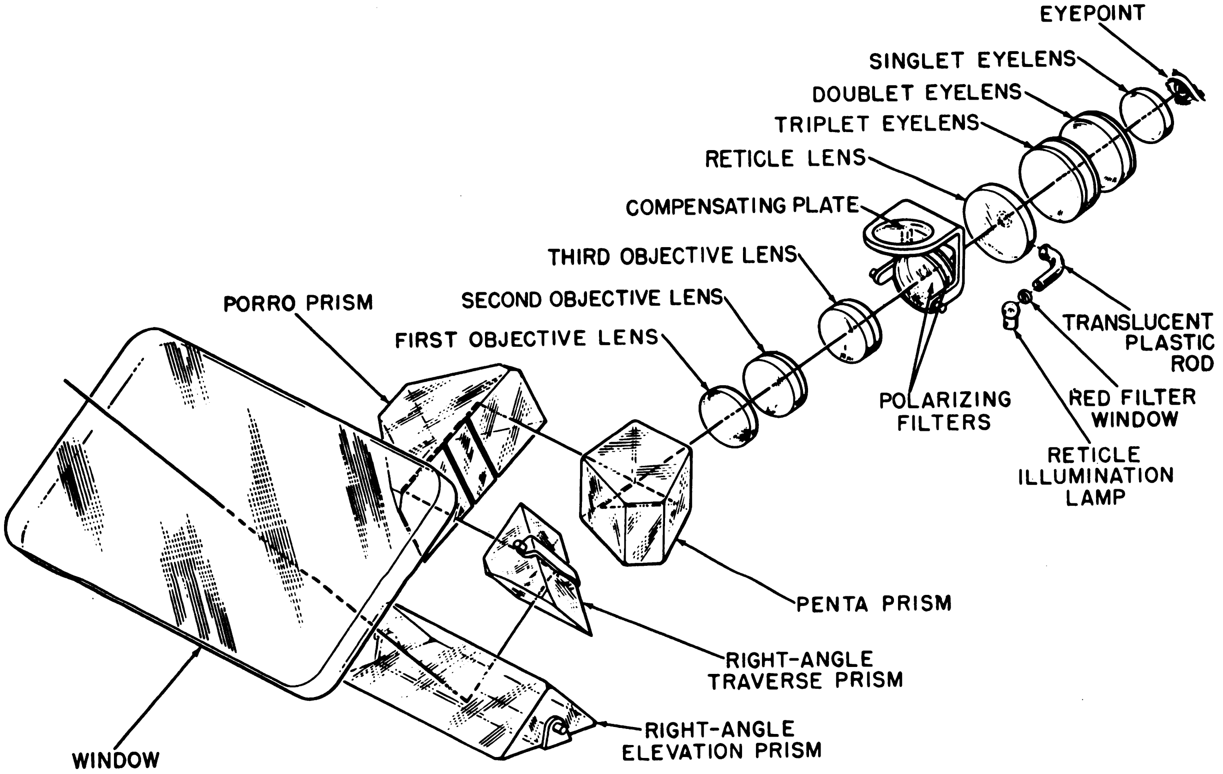

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Figure 3-22.—Telescope Mk 102 Mod 3; optical diagram.

(see figure 3-23). It is a movable mirror which reflects light into the traverse prism from targets at elevations between +85° and −20°. The mirror is a first-surface reflector. It is coated with aluminum that is covered with a glassy protective coating of silicon monoxide. It is trapezoidal in outline and is made of crown glass. Only the front face is polished; the other surfaces are ground.

The elevation assembly is rotated, by the elevation servo, about an axis parallel to both the bottom and front mounting planes of the telescope; thus, with the traverse prism at the zero

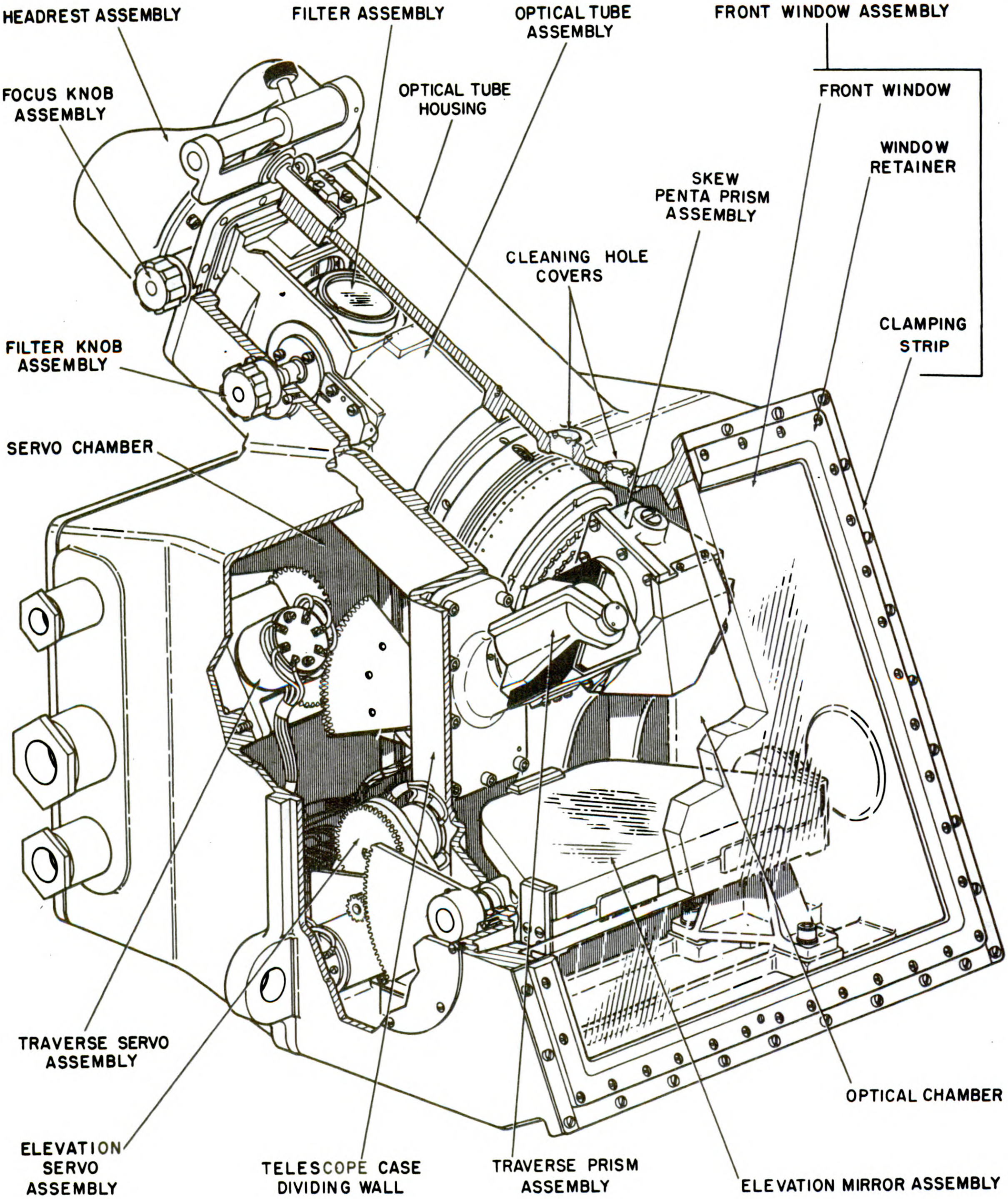

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Figure 3-23.—Telescope Mk 102 Mod 2; cutaway view.

position, the line of sight moves in a plane perpendicular to the two mounting surfaces.

The elevation mirror and the traverse prism form the movable portion of the line of sight. This movable portion must deliver target rays to the fixed portion of the telescope. The fixed portion begins with the entrance axis of the skew penta prism.

TRAVERSE PRISM.—The traverse prism is housed in the traverse prism assembly over the rear part of the elevation mirror. The traverse prism is a movable right-angle prism. It reflects light from the elevation mirror along the entrance axis of the fixed skew penta prism. The traverse prism is silvered on the hypotenuse side.

The traverse prism assembly is rotated by the traverse servo about an axis that lies in a plane perpendicular to both the bottom and front mounting planes of the telescope. This axis lies 30° forward of and perpendicular to the bottom mounting plane. Thus, that portion of the line of sight between the mirror and the traverse prism moves in a plane parallel to the elevation axis.

SKEW PENTA PRISM.—The skew penta prism is a fixed penta prism. It is oriented to reflect the image from the traverse prism through an angle of 90°, in a plane inclined approximately 22° to the telescope bottom reference plane, into the objective lens. In the interest of minimizing the size of the instrument, this reflected light also is dropped 32.6 millimeters.

ASTRONOMICAL TELESCOPE.—The remaining elements in the optical system form an astronomical telescope. The objective lens, filter assembly, and reticle plate are housed in an optical tube. The axis of the tube is inclined 22° to the telescope bottom reference plane. The field lens, intermediate lens, and eye lens are housed in the eye lens housing assembly, which is coaxial with the optical tube.

The objective lens is a cemented achromatic doublet. It is held in an objective mount located on the front end of the optical tube. This objective mount contains eccentric rings to provide adjustment around the optical axis and a focusing ring to provide adjustment along the optical axis.

The reticle plate is circular with parallel faces. The reticle pattern is etched on the first surface. It consists of two concentric circles having true field diameters of 3 mils and 15 mils. Reticle lines appear 1.25 minutes wide. The edge of the reticle plate is polished to transmit light from the reticle illumination lamp.

The reticle is illuminated through a frosted window, which provides diffused, low-intensity light. A slight change in the size of this window is the only optical difference between Mods 2 and 4.

The filter assembly, located between the objective and the reticle, consists of a variable density filter and a compensating plate.

The eyepiece consists of a field lens, an intermediate lens, and an eye lens. The field and intermediate lenses are mounted in a cell that can be moved longitudinally. The eye lens is fixed.

AUTOCOLLIMATION MIRRORS.—An autocollimation mirror is provided as an accessory to the telescope. It is used to check the alignment of the line of sight with the two reference surfaces of the telescope. This mirror is mounted in front of the window so that it reflects the line of sight precisely back into the telescope when the line of sight is positioned exactly at 0° elevation and 0° degree traverse with respect to the reference surfaces. The mirror is circular in shape and is an aluminized first-surface reflector with a protective coating of silicon monoxide.

Optical System for Mod 3

The optical system of Telescope Mk 102 Mod 3 (figure 3-24) is functionally identical to the system used in Mods 2 and 4. It has two rotatable reflectors that move the line of sight in elevation and traverse. The fixed reflectors bring to the objective the target image acquired by the movable elements.

The optical system of Telescope Mk 102 Mod 3 offers an unobstructed field of view of 9°—4.5° about a tracking line that may be moved to the limits of the telescope.

ELEVATION PRISM.—The elevation prism is a right angle prism that supplies elevation movement to the line of sight and reflects the target image up into the traverse prism (see figure 3-24). The elevation prism is rotated by the elevation drive unit assembly about a horizontal axis parallel to the horizontal and vertical reference planes.

TRAVERSE PRISM.—The traverse prism is a right angle prism that supplies traverse movement to the line of sight and reflects the target image into the porro prism. It is rotated by the

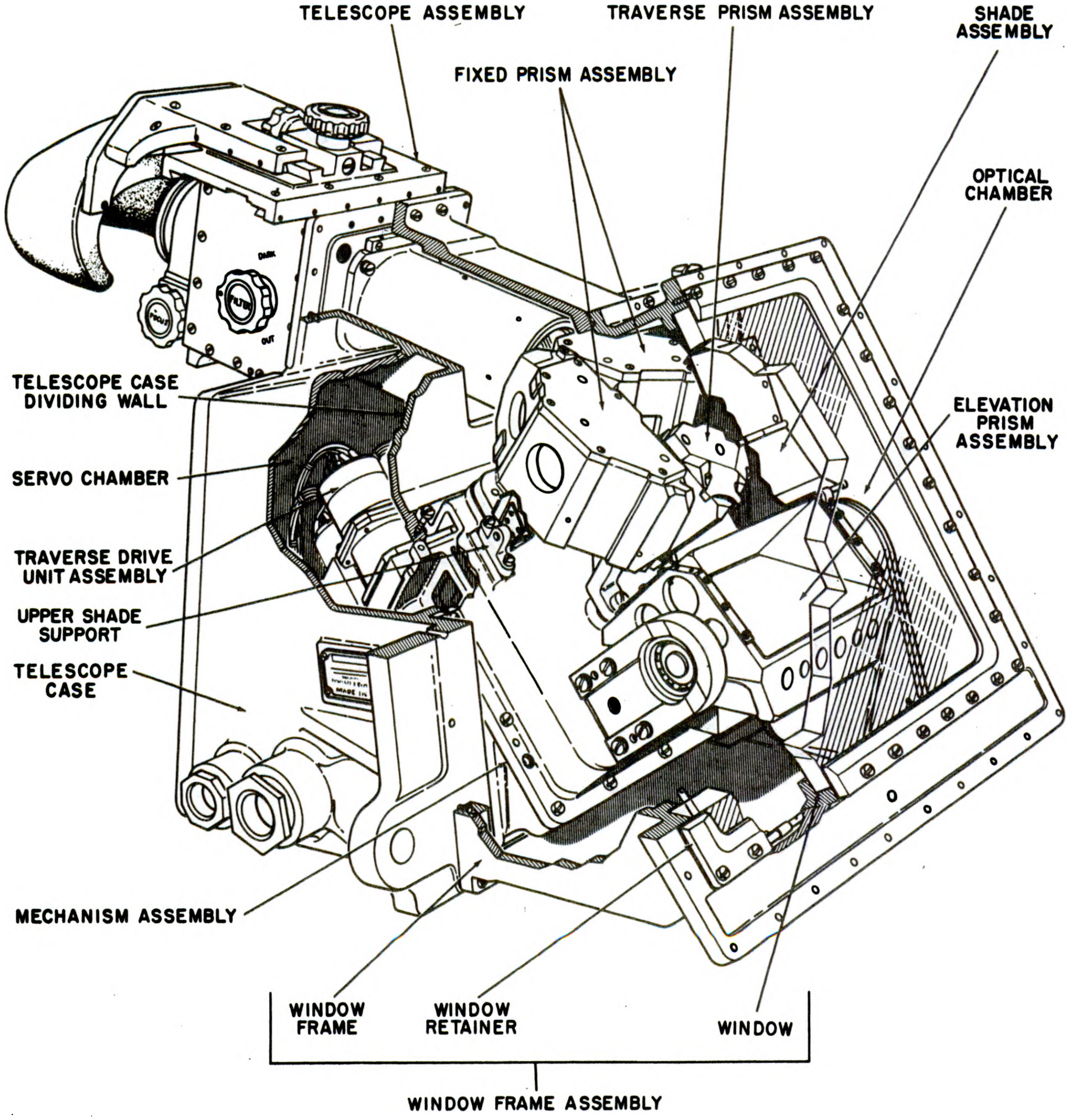

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Figure 3-24.—Telescope Mk 102 Mod 3; cutaway view.

traverse drive unit assembly about an axis slanted 37.5° back from the vertical reference plane. It lies in a plane perpendicular to the vertical reference plane.

PORRO PRISM AND PENTA PRISM.— The porro prism and penta prism are fixed prisms held in the fixed prism assembly. The porro and penta prisms are held in the fixed prism assembly at different angles with respect to the telescope bottom mounting surfaces. The porro prism is held at an angle of 39°, and the penta prism at an angle of 18.5°. The prisms are fixed at these angles to orient the line of sight with the axis of the remaining optical components in the optical system.

MK 102 MODS 5 AND 6 AND MK 116 MOD 0

A Mk 102 telescope, which incorporates solid state amplifiers and power supply, redesignates Mods 2 and 4 to Mods 5 and 6, respectively.

Optical System

The optical elements of the Mk 116 are identical to those of the Mk 102 Mods 2, 4, 5, and 6 with the exception of the window. The window is slightly different because of frame design. The illumination system contains fewer elements but functions the same. The characteristics of the optical system are the same as those of the Mk 102 Mods 2, 4, 5, and 6.

Model Differences

Although Telescopes Mk 102 Mods 5 and 6 and Mk 116 Mod 0 are interchangeable, differences exist between them. Mk 102 Mods 5 and 6 are similar but differ from Mk 116 Mod 0 in the designs of servo assemblies, limit stops, fuse box assemblies, and lamp housings. Also, the servo amplifiers, power supplies, and lamp dimming rheostats are located differently.

Maintenance Requirements

During the predisassembly inspection, checks are made to determine the extent of overhaul required. As in other optical instruments, they should be disassembled only as required for you to perform maintenance and return the instrument to operating condition.

Whenever practical, the predisassembly inspection should be made before the gunsight is removed from its mount. Because of the size and weight of the gunsight, removal and transportation can be hazardous. Repairs that can be made in place should be made in place. Repairs that might affect the alignment of the instrument should be performed in the shop because a collimation check is required.

Inspection should include all mechanical, optical, and electrical functions and components. Normally the mechanical inspection will be directed towards appearance and operation. All controls must operate smoothly over their full range, and the prescribed amount of gas pressure must be present.

The optical inspection should be directed at proper adjustment, cleanliness, and presence of moisture. The electrical inspection will be dictated by the type of gunsight being inspected. While all tilting-prism gunsight telescopes have reticle illumination, only the more recent types are driven by a servo/control-transformer mechanism. To make the electrical inspection, you activate each electrical system and check for proper operation.

If the instrument is removed from its mount, all mounting surfaces must be protected from damage since they are reference surfaces for alignment purposes.

Complete procedures for overhaul collimation and sealing/drying of the Mk 102 and Mk 116 telescopes are found in OPs 1858 and 4239.

Pressurization

All tilting-prism gunsight telescopes are charged internally with nitrogen. The nitrogen reduces the possibility of internal condensation of water vapor and fogging and slows down deterioration of internal components by oxidation.

The recommended pressurizing procedure involves three steps: pressure testing, drying, and charging.

PRESSURE TESTING.—The purpose of pressure testing is to ensure that the instrument is gas tight. In pressure testing, you introduce nitrogen into the instrument to a specified pressure; then you inspect for gas leakage. Leakage may be detected by means of a soap or an immersion test.

To perform the soap test, make a thick, frothy solution of soap and water. Apply this solution to all areas where a gas leak might conceivably occur. A gas leak will cause the solution to bubble.

The immersion test provides a more positive indication of gas leaks, especially small ones. Where practical, this test is recommended. To perform this test, immerse the pressurized instrument into a container of fresh water and look for bubbles of gas.

CAUTION: Do *not* use the immersion test on instruments, such as the Mk 102 and Mk 116, in which electrical components are not protected within the pressurized envelope.

DRYING.—The purposes of drying are to remove moisture from within the instrument and to displace air with nitrogen. Either the evacuation or purging method of drying can be used.

The evacuation method is similar to that used on submarine periscopes and is described in OM 3 and 2. Evacuation, which means pulling a vacuum, is the more efficient method because it removes more residual moisture than does purging.

Evacuation is accomplished by "boiling off" the moisture. As the pressure is reduced within a chamber containing water, a point is reached at which the water will boil though it is at room temperature. At 72 °F, the vacuum required to make water boil is approximately 29.2 inches of mercury (29.2" Hg). A vacuum of 29.6" Hg is required to boil water at a temperature of 53 °F. Evacuation removes residual moisture that may have penetrated pores in the metal and that purging might not remove. You should continue evacuating an instrument after the boiling point has been reached to allow the residual moisture to boil and be drawn off as water vapor.

The purging method eliminates moisture much like a sponge does. Dry nitrogen passing over residual moisture absorbs the moisture and carries it away. The only problem in purging is to get the nitrogen into all areas where moisture may be present.

CHARGING.—Charging is the method of pressurizing an instrument with dry nitrogen to a specified service pressure. You may use the method specified in OM 3 and 2 for submarine periscopes (cold trap method), or you may use the instrument dryer method. The cold trap method is preferred as it provides a lower dew point and therefore less chance of fogging of the instrument.

Collimation

The collimation of a tilting-prism gunsight telescope involves some of the standard checks of an optical instrument, such as zero diopters, focusing range, parallax, and squareness of the crossline. It also involves checks for determining whether the elevation and deflection systems are operating properly.

The elevation and deflection checks are unique to tilting-prism gunsight telescopes. Although the collimation setup varies for each telescope, the collimation procedure is basically the same. The elevation and deflection systems must move the line of sight with respect to a datum plane through specified limits of travel.

The setup for checking elevation and deflection systems of tilting-prism gunsight telescopes is basically the same for all telescopes. The setup equipment required includes the Mk 9 collimator, collimation fixtures, checking telescopes, and the test instrument. The procedure involves mounting the collimation fixture on the collimator support plate, aligning the collimator telescopes with the checking telescope, installing the test instrument, and performing the collimation tests and adjustments. Prior to installing a telescope on its support fixture, clean all foreign matter from the bearing surfaces.

Mk 102 and Mk 116 Alignment

These gunsights have the same requirements and test setups. The prime difference between them lies in their electrical systems and therefore does not affect the test configurations.

The limit of error in elevation and deflection is +2 minutes of arc. The elevation checks are made at −25 °, 0 °, and +85 °, while the deflection checks are made at +30 °, 0 °, and −30 °.

The alignment of the test fixtures and installation of the gunsight (figure 3-25) is similar to that of the Mods 2, 3, and 4 telescopes. On these instruments, input shafts were used to generate elevation and deflection angles.

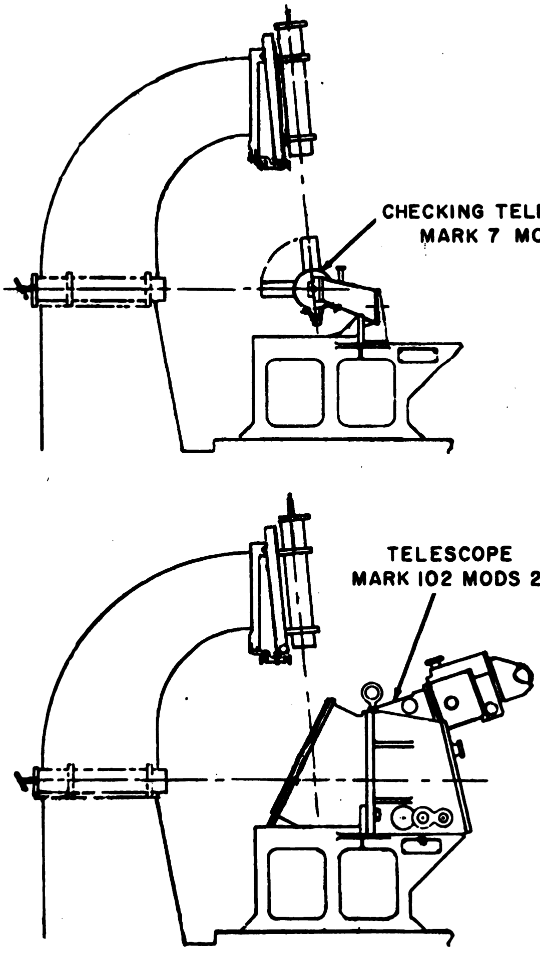

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Figure 3-25.—Arrangement for collimating telescopes Mark 102 Mods 2 and 3.

On the Mk 102 Mod 5 and 6 or Mk 116, no input shafts are used and elevation and deflection angles are generated electrically. This presents a slight problem for collimation purposes in that no mechanical angle inputs are available externally. However, you can manually generate elevation and deflection angles by removing the servo chamber cover and revolving the servo gear train by hand.

The final step in the alignment of the Mk 102 Mods 5 and 6 and Mk 116 is to set the servo assemblies so that electrical and optical zeros coincide. To accomplish this, you must energize the gunsight. If an "in-shop" electrical test arrangement is not available, the zero will have to be set after the assemblies are installed in the gun mount. Basically, you make the adjustment by generating a 0° elevation and deflection order. You then rotate the 36X control transformer until a 0° optical elevation and deflection is attained.

This is easily accomplished with the autocollimation mirror installed. The reflected image must align with the reticle image in both elevation and deflection.

CHAPTER 4

RANGEFINDERS

The rangefinder is another optical instrument used in the solution of the fire control problem discussed in the previous chapter.

In the not too distant past, rangefinders were the primary source of range information aboard naval combatant vessels. Today they serve as auxiliary or backup systems with radar serving as the primary source of range information.

In addition to fire control, the rangefinder can provide range information for navigation purposes. At short ranges, this information can be extremely accurate. Rangefinders can also be used in situations which prohibit the use of radar, such as those that require EW/CON consideration or when the target will not produce a radar image. The Mk 21 rangefinder—a small, portable, coincidence type—is used primarily for this purpose.

This chapter will deal mainly with the Mk 21 rangefinder. Most repairs to fire control rangefinders are normally handled at the shipyard level, or higher.

ANGULAR MEASUREMENTS

All optical rangefinding devices are capable of measuring angles. These angles are measured in one of three different units: degrees, radians, or mils.

DEGREES

The most common unit of angular measure is the *degree*, which is defined in terms of rotation. Imagine a circle with one radius drawn in. Pivot the radius at the center of the circle and turn it through one complete revolution back to its original position. In making one complete revolution, the radius has generated an angle of 360°. Or looking at it another way, divide the circumference of the circle into 360 equal parts, and mark off the divisions. A radius, in rotating from one mark to the next, will generate an angle of one degree.

With the help of optical instruments, we can measure angles smaller than one degree. Each angle is divided into 60 smaller units, called *minutes*, and each minute is further divided into 60 *seconds*. The complete system of angular measurement shapes up like this:

360 degrees equal one complete circle
60 minutes equal one degree
60 seconds equal one minute

The second is the smallest independent unit of angular measure; to measure more precisely by seconds, you will have to use fractions of a second.

TRIANGULATION

In ancient Egypt farmers in the Nile valley discovered the principle of triangulation to measure distances that could not be reached directly. This principle is used in rangefinding. Modern surveyors use triangulation to measure distances they cannot get at directly. Astronomers use it to measure the distance of the sun, the planets, and some of the nearer stars.

You should already have a good knowledge of the principle of triangulation, but we will run through it just for review. Triangulation is based on the principle of similar triangles. (Two triangles are similar when the three angles of one triangle are equal, respectively, to the three angles of the other.) The two triangles

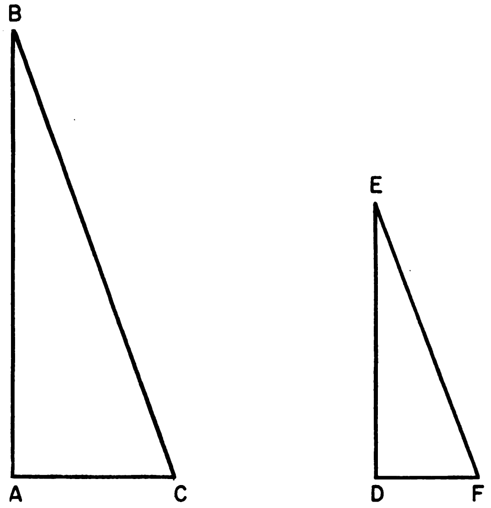

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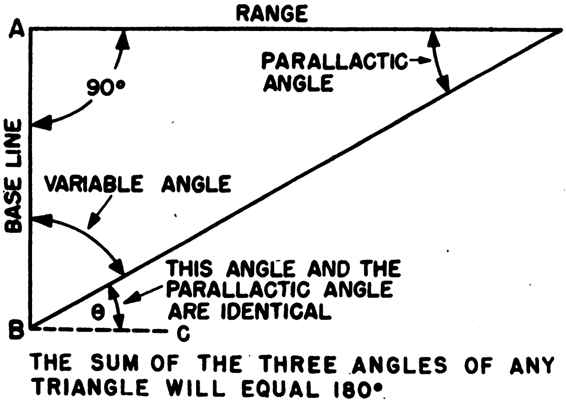
Figure 4-1.—Similar triangles.

in figure 4-1 are similar. In any pair of similar triangles, the relationship between corresponding parts is constant. Measure the lines AB and BC, and then divide the length AB by the length BC; if your measurements are accurate, your answer will be 0.9397. Do the same thing with the corresponding parts of the smaller triangle; measure DE and EF, and divide DE by EF. Your answer will be 0.9397 again.

If you divide AC by BC you will get 0.3420. You can do the same thing with corresponding parts of the smaller triangle, or of any triangle similar to these two; the answer will always be the same.

Look at figure 4-2. It illustrates the principle of triangulation and shows the fundamental triangle of a rangefinder. Assume you are on a ship at point A and want to measure the range of another ship at point P. You can solve that whole triangle and calculate the range AP by measuring only those parts of the triangle that are on your ship. How? By comparing APB with some similar triangle. You know that angle A is a right angle; you can measure angle ABP by setting up a surveyor's transit at Point B somewhere on your ship. Now you can easily calculate angle P, because you know that in any triangle the sum of the angles is equal to 180°.

But how can we calculate the range from the facts we know about this triangle? We can calculate the range by setting up an equation that contains the distance we want to find (AP, the range) and other known quantities. What do we already know? We know the length of the side AB and the value of all three angles.


RANGE
A
P
PARALLACTIC ANGLE
90°
BASE LINE
VARIABLE ANGLE
THIS ANGLE AND THE PARALLACTIC ANGLE ARE IDENTICAL
θ
B
C
THE SUM OF THE THREE ANGLES OF ANY TRIANGLE WILL EQUAL 180°

148.9

Figure 4-2.—The fundamental triangle of a rangefinder.

In a right triangle, the side opposite one of the acute angles divided by the side adjacent to that angle is the tangent of that angle. Applying this fact to our triangle shown in figure 4-2, we get

$$\tan P\angle = \frac{AB}{AP}\,.$$

Solving for the range, AP, we get

$$AP = \frac{AB}{\tan \angle P}\,.$$

We can look up tan P in a table of trigonometric functions and solve for AP.

As you can see, by using the method of a surveyor, we can calculate the range of a target without leaving our own ship. But we can do it much more quickly with a rangefinder.

In figure 4-2 consider the points A and B to correspond to the two end windows of a rangefinder. In this case the line AB corresponds to the base of the rangefinder and is always constant for that particular rangefinder. You cannot measure the *parallactic angle* (angle P) directly, because its vertex is aboard the other ship. But if you imagine a line (BC) parallel to AP, then angle θ (Theta) will be identical with the parallactic angle and can be easily measured.

The rangefinder has all the information needed to solve the triangle and calculate the range.

In the triangulation formula

$$\tan \angle P = \frac{AB}{AP},$$

you can substitute $\tan \theta$ for its equal $\tan \angle P$. Since AB corresponds to the base of the rangefinder, let B represent the base in yards, and R represent the range (AP) in yards. Now the formula is

$$\tan \theta = \frac{B}{R}.$$

You can see that the range will always be large when compared with the base of the rangefinder, and therefore the angle θ will always be very small. Now this may be surprising, but it is true: For very small angles, the tangent of the angle is almost exactly equal to the angle itself *when the angle is expressed in radians*. So if θ is in radians, then

$$\theta = \frac{B}{R}.$$

Now you have the *rangefinder formula*.

But suppose you want to express θ in seconds rather than radians. There are 206,265 seconds in one radian. Therefore,

$$\theta = 206{,}265 \frac{B}{R} \text{ seconds.}$$

From this formula, you can calculate the value of the parallactic angle, (θ), for any given rangefinder at any given range. However, the job of the rangefinder itself, of course, is to measure θ and convert it into yards of range for you.

You may estimate the relative distance of two objects by comparing their parallactic angles. Since a nearby object has a greater parallactic angle than a distant one, you know that the object with the greater parallactic angle is closer than the other.

Of course the usefulness of a rangefinder is limited, because your stereo-acuity is limited. Two parallactic angles will appear to be equal to the average trained observer unless the difference between them is 12 seconds or more. Since the base of a rangefinder is short, its effectiveness is limited to comparatively short ranges.

How can we extend the range? Consider two distant objects of which the parallactic angles are 1 second and 2 seconds. To the naked eyes, of course, they will appear to be at the same distance; the difference in their parallactic angles is too small to detect. You cannot tell which of these objects is closer unless you find some way to increase the difference between their parallactic angles to 12 seconds or more.

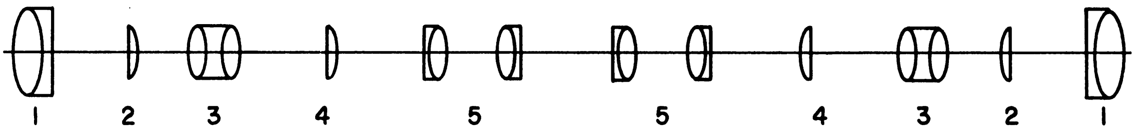
Now suppose that you mount two 12X (12 power) telescopes side by side and parallel with the centers of their eyepieces about 65 millimeters apart. You can look through one of these telescopes with one eye and through the other one with your other eye. The telescopes will magnify both objects 12 times and thus increase their parallactic angles to 12 seconds and 24 seconds, respectively. The difference is now 12 seconds, and you can estimate the relative distance of the two objects.

You could also extend the range of your depth perception if increasing your interpupillary distance were possible. You can easily see that for an object at any given distance increasing the base of the triangle will increase the parallactic angle.

The optical rangefinder uses both of these means to extend the range of your depth perception. It provides you with a magnified image of the target. It also provides you with two lines of sight through its two end windows, which are much farther apart than the pupils of your eyes. By using a rangefinder with a magnification of 24X and a base length 100 times your interpupillary distance, you can increase your depth perception by a factor of 2,400.

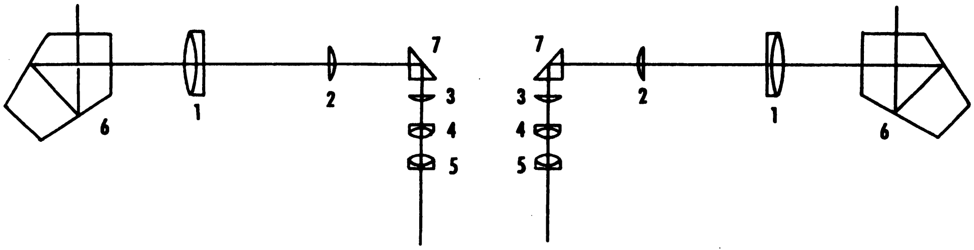
OPTICAL SYSTEM

You can understand how the optical system of a rangefinder works if you compare it with other instruments you have already studied. In



148.11

Figure 4-3.—Telescopic system of a rangefinder.



148.12

Figure 4-4.—Basic optical system of a rangefinder.

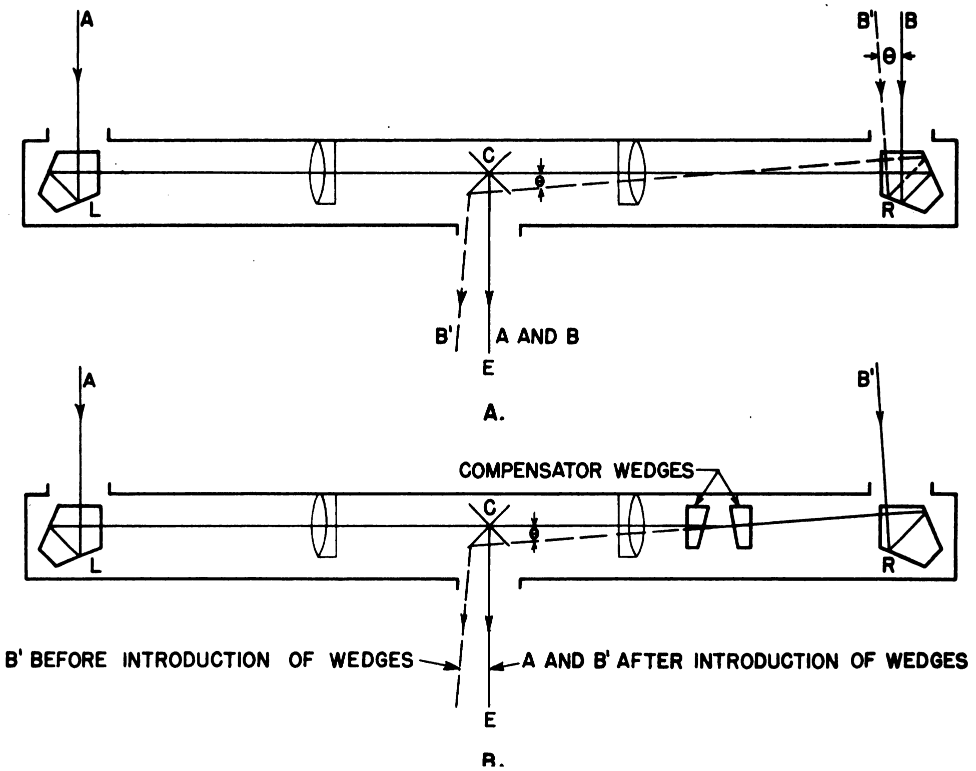
figure 4-3 you see two simple gunsight telescopes laid out with all their elements in a straight line. The two eyepieces (doublets) face inward; the two objective lenses are at the ends of the line. Since you now have two lines of sight through two separate telescopes, you have the essential elements of a rangefinder. But to make it useful, you will have to add a few components. Your two lines of sight are pointing in opposite directions; actually, you want them to converge on a single object. You can do this by adding two reflecting surfaces on the optical axis—one beyond each objective—to deflect the lines of sight forward. To make the incident rays enter your eyes, you must add two more reflecting surfaces to the axis, one near each eyepiece. Such an optical system is shown in figure 4-4.

A penta prism is used at each objective to reflect rays from the target onto the optical axis. The added prisms (numbered 7) reflect the rays to the observer's eyes. This system will increase your depth perception tremendously. It magnifies your target and effectively increases your interpupillary distance. By using this system, you can easily estimate the relative distance of two objects, even at a great distance. But estimating relative distance is very different from measuring actual distance. To make this system into an effective rangefinder, you must add a measuring device.

The two diagrams in figure 4-5 are schematic drawings of a coincidence rangefinder—the type with a single eyepiece. The cross at C represents a coincidence prism. This prism enables you to see with just one eye through both telescope systems at once. The field of view appears to be split by a horizontal line. The lower half of the image is formed by one of the telescopes, the upper half by the other.

Look at the upper diagram. The rangefinder has been turned so that ray A from the target is at a right angle to the optical axis. After reflection in the left penta prism (L), ray A will coincide with the axis. It will then strike the center of the coincidence prism at C and will be reflected to the observer's eye at E.

If your target were at infinity, all rays from a given point on it would be parallel. The ray entering the right penta prism (R), would behave


A
B'
B
θ
C
θ
L
R
B'
A AND B
E
A.
A
B'
COMPENSATOR WEDGES
C
θ
L
R
B' BEFORE INTRODUCTION OF WEDGES
A AND B' AFTER INTRODUCTION OF WEDGES
E
B.

148.13

Figure 4-5.—The rangefinder principle.

like ray B. It would be reflected along the axis; after reflection at the coincidence prism, it would coincide with ray A. The two halves of the image would appear to the observer to coincide and form one unbroken image.

Actually your target will be at a finite distance. The broken line (B′) represents a ray from a target at this distance. It will strike the face of the right penta prism at a slight angle—the parallactic angle (θ). After reflection in the penta prism, it will diverge from the axis at the angle θ; after reflection in the coincidence prism, it will fail to coincide with A. The observer will see a broken image of the target; half the image will be displaced to one side.

In the lower diagram, two compensator wedges are inserted. Think of them as a pair of thin prisms. A prism, of course, will deviate a ray of light toward its base. If you choose the prisms carefully, you can get a pair that will deviate the ray (B′) through angle θ. Then after the ray passes through the compensator wedges, it will lie on the optical axis; the observer will see an unbroken image of the target.

If necessary, you could actually measure ranges by trial and error. You could select one or more prisms until you found the ones that would make the image halves coincide. Since the deviation of these prisms is the angle θ, you could calculate the range. But this method is slow, and therefore not pratical.

Actually, rangefinders use a much simpler principle. The compensator wedges are mounted so that you can rotate them on their axis by turning a knob. The deviation will vary with the amount of rotation. By turning the ranging knob, you can rotate the wedges until their deviation is equal to θ. A scale is mounted on this system to indicate the amount of rotation. By suitable tests on targets at known distances, the scale can be calibrated to show the range in yards.

This is the basic principle of the rangefinder. There is more to it than that, of course, but the other elements are accessories. They help to make the instrument more accurate and more convenient to use and provide an easy means of calibrating it.

TYPE OF RANGEFINDERS

The Navy uses two types of rangefinders: *coincidence*, and *stereoscopic*. These two instruments have many features in common. Each consists of two telescopes, one in each half of the instrument. Both measure the parallactic angle and calculate the range from that measurement. They mainly differ in the way the target image is presented to the operator's eyes.

The coincidence rangefinder has a single eyepiece. The operator's field of view is split by a horizontal line. The upper half is formed by one of the two telescopes, the lower half by the other. To operate the coincidence rangefinder, the operator turns the ranging knob—thus rotating the compensating wedges—until the two halves of the image coincide. The operator can then read the range, in yards, on the scale. When the rangefinder is not set to the proper range, the operator sees a broken target; half of the image is displaced to one side (figure 4-6.)

The stereoscopic rangefinder has two eyepieces. In ranging with this instrument, an operator makes use of his own stereo-acuity—his ability to estimate the relative distance of objects. When looking through the eyepieces, the operator sees a single, unbroken image of this target. Superimposed on that image he sees a pattern of reference marks. (This pattern is engraved on the reticles in the two telescopes of the rangefinder.) Figure 4-7 shows a typical reticle pattern for a stereoscopic rangefinder.

To the operator, this reticle pattern will appear to be spread out in space—some of the vertical marks will appear to be closer than the diamonds; others will appear to be farther away. (This is an illusion—or ''artificial'' stereoscopic effect much like 3-D. The patterns of the two reticles are similar but not identical. By viewing a separate reticle with each eye, you get an effect of stereopsis, and the pattern appears to be spread out in space.)

The center row of reference marks (the diamonds, in figure 4-7) may appear to the rangefinder operator to be closer or farther away than the target. By turning the ranging knob, and thus rotating the compensating wedges, the operator can make the target appear to move farther away or closer. When the target and the diamonds appear to be at the same distance, the rangefinder is properly set; the operator can then read the range on the scale.

In naval use, the steroscopic rangefinder has largely replaced the coincidence type. When operators are thoroughly trained, they find no significant difference in the accuracy of the two types of rangefinders. However, when ranging on

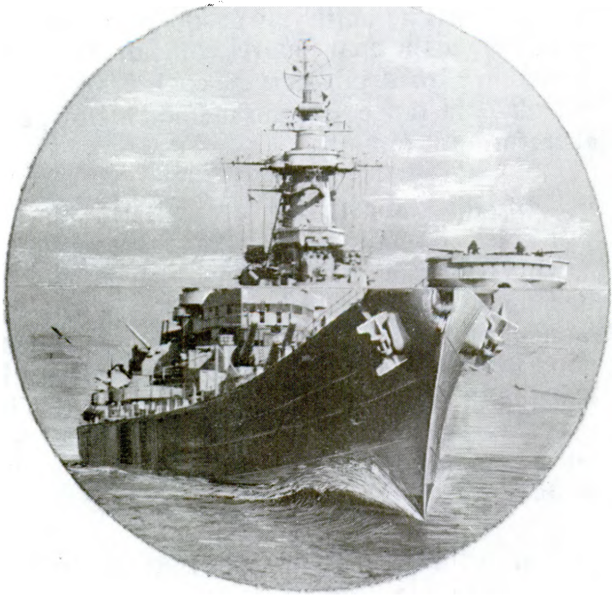


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Figure 4-6.—Field of view of the coincidence rangefinder.

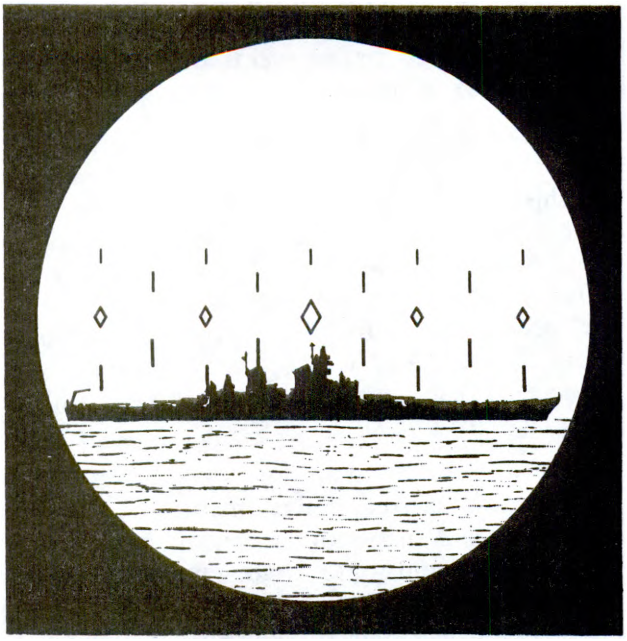

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Figure 4-7.—Field of view in a stereoscopic rangefinder.

aircraft, or under conditions of poor visibility, a skilled operator can usually get better results with the stereoscopic rangefinder.

COINCIDENCE RANGEFINDER

The main optical systems of the coincidence rangefinder include the following elements: end windows, penta prisms or end reflectors, compensating wedges or measuring wedges, correction wedges, main objective lenses or objective group, astigmatizers, and color filters. Some instruments include change of magnification lenses. Figure 4-8 (a foldout at the end of this chapter) shows the optics of a typical coincidence rangefinder. Refer to this illustration as you study these elements.

End Windows

End windows are mounted in the front of each end box of the rangefinder. These windows are tightly sealed around the edges to keep dirt and moisture out of the instrument. Although the two surfaces of each window have been ground optically flat, they are not quite parallel. Each end window is actually a prism, though a prism of extremely small angle.

By a suitable rotation of an end window, you can make its deviation zero in the plane triangulation. The plane of triangulation is the plane determined by the halving line of the rangefinder and the sighting point on the target. You can also deviate the incident rays slightly to either the right or the left. Since the end window can deviate the incident rays, they provide a means of compensating for slight inaccuracies in the reflecting angles of the penta prism. An index, and in some instruments, a graduated scale, is on the outer edge of each end window, or on its frame, to show the setting. (On some rangefinders, the left end window is plane-parallel and only the right end window is used for corrections.)

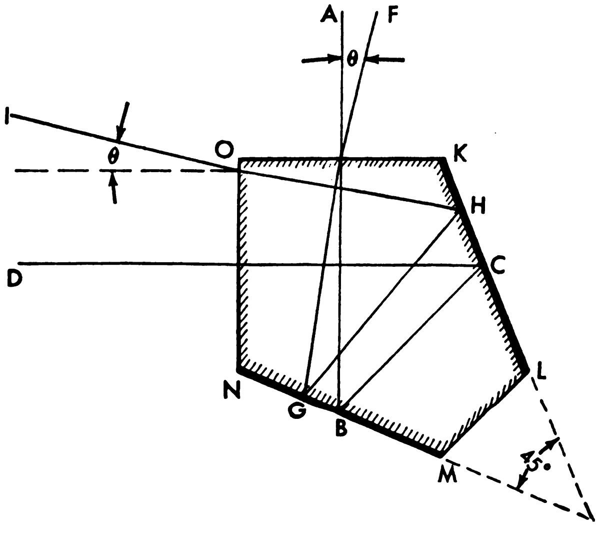
The end windows are set during the final inspection of the rangefinder, after it is manufactured and after each overhaul. When the rangefinder has become thoroughly stabilized at a normal temperature, the inspector checks the internal adjustment. Then one or both end windows are rotated to secure a correct reading on an accurately known range. Normally, resetting the end windows is not necessary.

End Penta Prisms or End Reflectors

The penta prisms or end reflectors (often called penta reflectors) deviate the line of sight through an angle of 90°. In most rangefinders the deviation in the right penta prism or end reflector, although constant, is slightly less than 90°. A penta prism, by reflecting the image twice, produces an erect, normal image. (A plane mirror or a right-angle prism could not be used for this purpose because the image would be reverted. The deviation of a right-angle prism is not constant—it is 90° only if the incident light is normal to the first surface.)

In large, long-base rangefinders, the objective lens must be quite large to make the field of view wide enough. These instruments use end reflectors rather than penta prisms. An end reflector consists of two plane mirrors rigidly mounted together at an angle of 45°. The path of light within it is the same as that in a penta prism. (See figure 4-9.) As you study this diagram, you will see that the deviation is constant, regardless of the angle of incidence. Although the light is refracted at both outside surfaces, the two refractions are equal and in opposite directions. Since the surface refraction can be disregarded, you can see that an end reflector works in exactly the same way as a penta prism.

In a long-base rangefinder, the end reflector has two advantages over the penta prism. First, it is less expensive than a penta prism of sufficient size. Second, and more important, a large end reflector responds quickly to temperature changes. After a change in temperature, the end reflector stabilizes within a short time. A large



148.16

Figure 4-9.—Principle of the penta prism and the end reflector.

penta prism, on the other hand, responds slowly, since glass is a poor conductor of heat. For some time after a temperature change, various parts of a large penta prism are at various temperatures and cause distortion and inaccuracies.

Deviating Wedges

There are two general types of deviating wedges: (1) a single measuring wedge, mounted so that you can slide it along the optical axis of the instrument; and (2) two compensator wedges, so mounted that when you turn the ranging knob, the two wedges rotate equally and simultaneously in opposite directions about the optical axis.

Figure 4-10 illustrates the action of a single measuring wedge. A measuring wedge is mounted on the longitudinal axis of the instrument between the objective lens and its image plane. The deviation of the wedge is constant. But the displacement of the line of sight at the image plane depends on the position of the wedge along the axis. For any angle θ, and therefore for any specific range, a certain position of the wedge on the axis will make the two images coincide. A pointer is rigidly attached to the wedge and travels over a fixed scale to measure ranges. You calibrate the scale by marking the position of the pointer when targets coincide at accurately known ranges.

The incident ray, as usual, diverges from the end reflectors by the angle θ. The prism will deviate that ray toward its base. For any given angle θ, you can select a prism with exactly the deviation necessary to make the incident rays parallel to the axis as they approach and strike the objective. When the rays are parallel to the axis at the right objective (as they are at the left objective), the two images will coincide.

As mentioned before, this method could be used to measure ranges by trial and error. With a large assortment of prisms handy, you could try them out, one by one, until you found one with exactly the deviation necessary to make the rays parallel to the axis.

Any prism, as you know, will deviate the incident rays toward its base. With the base toward the target (as in figure 4-11) or toward the operator, all the deviation will be in a horizontal plane. If the base were up or down, all the deviation would be in a vertical plane. If you turned the base to some angle between zero and 90°, the rays would be

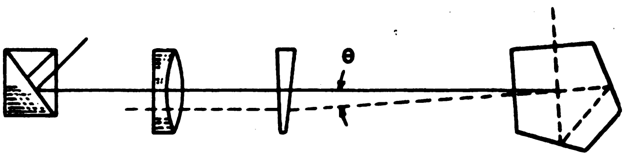


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Figure 4-11.—Action of the compensator wedges.

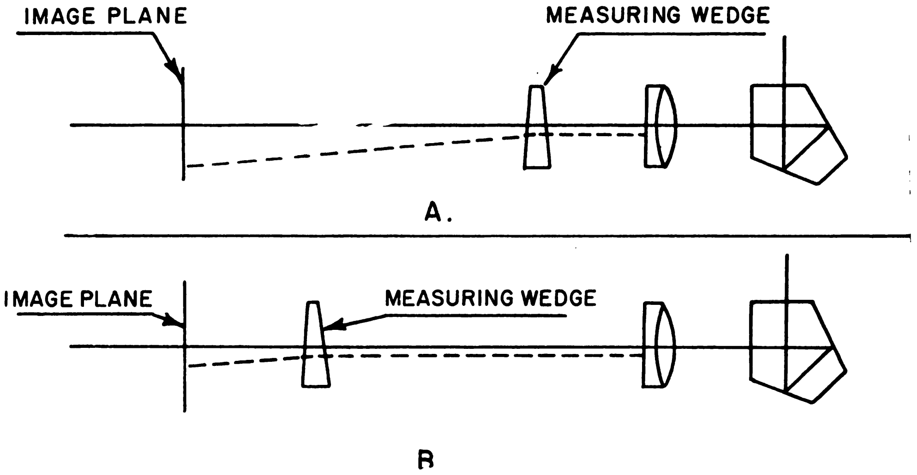

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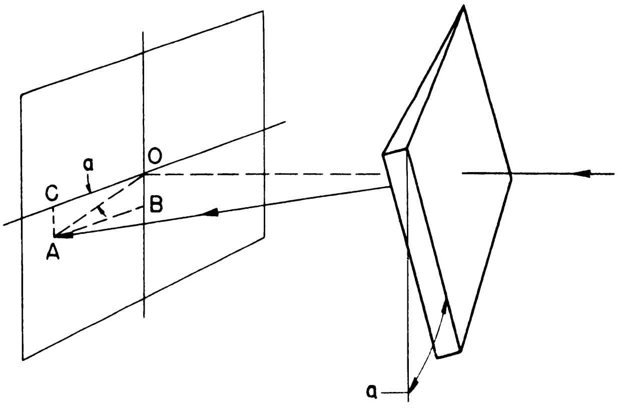
Figure 4-10.—Action of the single measuring wedge.



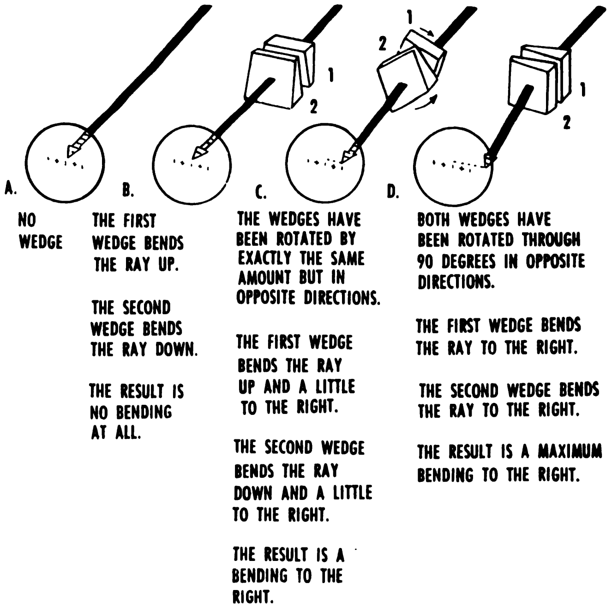
55.295
Figure 4-12.—Effect of rotating a single wedge.

deviated both horizontally and vertically at the same time.

Figure 4-12 shows what happens when you rotate a single wedge about the optical axis. A screen is used to intercept the deviated ray to show what happens to it. Line AO shows the total deviation of the ray toward the base of the prism. CA is the vertical component of the deviation, and BA is the horizontal component. If you keep the wedge at a fixed distance from the screen, then the total deviation (OA) will be constant, regardless of the angle of rotation. But as you rotate the wedge, the horizontal and vertical components will change. The horizontal component of deviation (BA) is the one you need to reduce the parallactic angle to zero. The vertical deviation must be eliminated entirely; otherwise the halving line will fail to split the image—the images will either spread out, or overlap.

By using two wedges rotating through equal angles but in opposite directions, you can keep the horizontal deviation and eliminate the vertical deviation. Let's look back at figure 4-5 and review the function of the compensator wedges. They are thin, achromatic prisms that can be used to deflect the line of sight in one telescope back through the angle θ, so that two images may coincide. The two compensator wedges are mounted on the axis of the right-hand telescope, outboard of the objective. Figure 4-13 shows how compensator wedges work. (Remember that a prism always deviates the ray toward its base.)

Since the range is always large compared to the base of the rangefinder, the parallactic angle is always small. The compensator wedges, therefore, are prisms of very low power—the angle is sometimes so small you cannot tell which side of the disk is its base. For this reason a small mark is etched at the edge of most wedges. It represents a line from the center of the base to the apex of the prism.


A.
NO WEDGE
B.
THE FIRST WEDGE BENDS THE RAY UP.
THE SECOND WEDGE BENDS THE RAY DOWN.
THE RESULT IS NO BENDING AT ALL.
C.
THE WEDGES HAVE BEEN ROTATED BY EXACTLY THE SAME AMOUNT BUT IN OPPOSITE DIRECTIONS.
THE FIRST WEDGE BENDS THE RAY UP AND A LITTLE TO THE RIGHT.
THE SECOND WEDGE BENDS THE RAY DOWN AND A LITTLE TO THE RIGHT.
THE RESULT IS A BENDING TO THE RIGHT.
D.
BOTH WEDGES HAVE BEEN ROTATED THROUGH 90 DEGREES IN OPPOSITE DIRECTIONS.
THE FIRST WEDGE BENDS THE RAY TO THE RIGHT.
THE SECOND WEDGE BENDS THE RAY TO THE RIGHT.
THE RESULT IS A MAXIMUM BENDING TO THE RIGHT.
1
2
1
2
1
2

148.18
Figure 4-13.—Refracting a ray of light with two compensator wedges.

Earlier in this chapter, you were told that the deviation in the right-hand penta prism or end reflector is less than 90°. To understand why, first consider what would happen if the deviation were exactly 90°. Then, for a target at infinity, the incident ray would be deviated parallel to the optical axis. Since the parallactic angle is zero, no deviation would be needed in the compensator wedges to make the two images coincide. For a target at infinity, you would turn the base of one wedge up and the base of the other one down, as in view B of figure 4-13.

For a target at the minimum measurable range, the incident rays would deviate from the optical axis, toward the operator, at the maximum parallactic angle. To make them parallel to the axis would require maximum deviation away from the operator; consequently, you would turn the compensator wedges so that both of their bases were toward the target. Obviously no rangefinder can measure a range greater than infinity or less than the minimum measurable range. To cover the whole span of measurable ranges, the wedges would need to rotate only through 90°; all measurable ranges would be crowded into 90° on the scale.

You could read the scale more accurately by expanding the calibrations to cover 180°. You can do so by making the deviation in the right penta prism or end reflector less than 90° (by making the angle between the two reflecting surfaces less than 45°). In this case, rays from a target at infinity would be deviated away from the axis and back toward the target. To make the images coincide, you would turn the wedges so that both bases are toward the operator. For a target at mean range, the incident rays would be parallel to the axis after deviation by the penta prism or end reflector. They would require no deviation at the wedges. You would turn one wedge base up and the other wedge base down. At minimum range you would have maximum deviation toward the operator. You would compensate for it by turning both wedge bases toward the target. In this system, as you can see, you need 180° of rotation of the wedges to cover the full span of measurable ranges. Consequently, the calibrations would be spread through 180° on the scale.

Correction Wedge

Correction wedges provide a means for correcting errors in alignment. Like the measuring wedge, the correction wedge is a thin prism of low power. In some instruments it is achromatic; in others it is not. It is located in the left-hand telescope and mounted so that it can be rotated by the operator. Rotation of the wedge deviates the line of sight both vertically and horizontally. The deviation in the plane of triangulation is the most useful; errors in horizontal alignment are corrected by adjustment of the optical bars or by adjustment of the height adjuster linkage. Such adjustment raises and lowers the end of the optical bar.

Rangefinder operators sometimes disagree as to when the two halves of the image coincide. Some operators who habitually make errors in ranging may find that these errors are fairly constant. With experience they can learn the usual amount of these errors and adjust the correction wedge to correct them.

Coincidence Prism

The coincidence prism (figure 4-8) has three functions: (1) to bring the images formed by the two objectives to a common focal plane where they can be viewed by the eyepiece; (2) to erect the images; and (3) to suppress the upper half of the right image and the lower half of the left image. Figure 4-14 shows how the coincidence prism accomplishes these functions.

Light rays from the left objective enter prism A and are reflected horizontally 90° toward the eyepiece. Half of these rays are reflected upward by the second reflecting surface of prism A, forming the upper half of the target image. The rays above the center of the prism are lost because they do not strike the second reflecting surface of prism A.

Light rays from the right objective strike prism B of the coincidence prism and are reflected down into prism C. The first and second reflecting surfaces reflect the rays horizontally toward the eyepiece; the third reflecting surface reflects the rays upward toward the eyepiece. Only the upper portion of the eyepiece rays are transmitted to the eyepiece because a metal shield serves to crop the lower portion of the rays.

Prism D is cemented to prism C. The image of the target is formed at the exit faces of prisms A and D, which are aligned with the plate (figure 4-14). The halving line (line which divides the two halves of the image) is located where prisms A and D are cemented together.

The four prisms (A, B, C, and D) are cemented together to form a single unit. The entrance faces of prisms A and B are coated with magnesium fluoride.

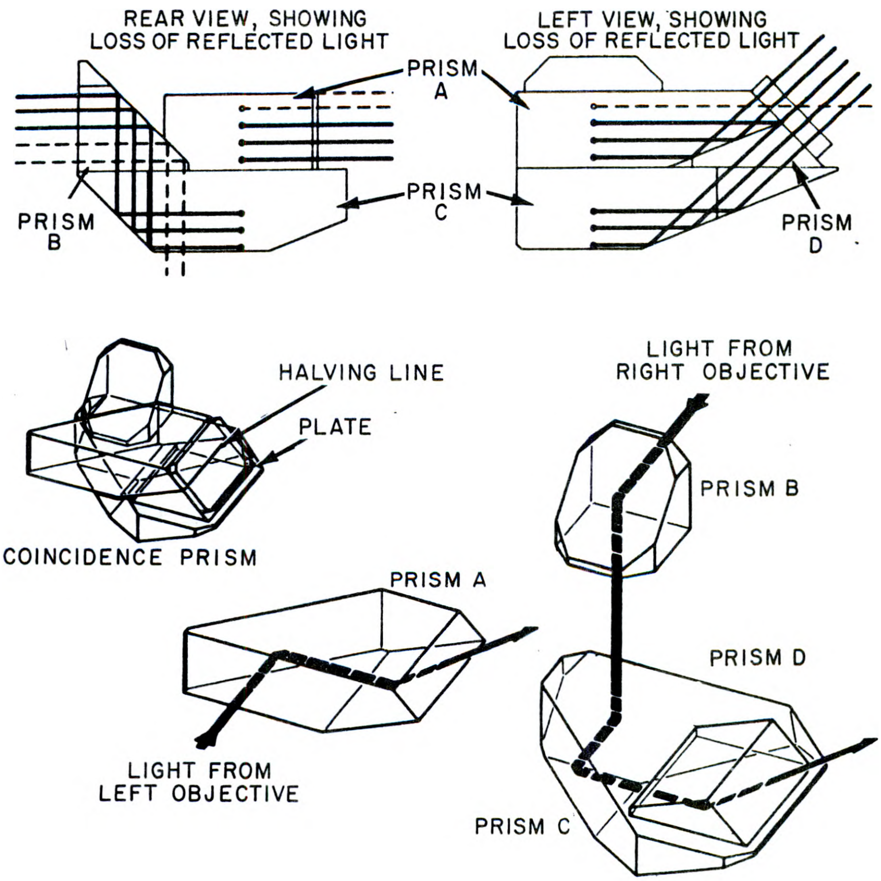
Objective Lenses

The function of the objectives is to form real images of the target on the reticles. The objectives are made and mounted with great precision. If the focus of the objectives are not exactly alike, the magnification of the images in the right and left eye will differ, and the range readings will be incorrect. Lack of uniformity in the focus of objectives is revealed when an observed target is not in the center of the field. The right and left objective lenses are therefore selected and adjusted to give the same focus. They are composed of positive lenses of crown glass and negative lenses of flint glass. The objective mounting and the spacing between the lenses are carefully adjusted to give the correct focus and are held firmly in their mounts without strain.

Eyepiece Group

The eyepiece group is used to view and to magnify the composite image reflected by the coincidence prism. The eyepiece has a focusing mount. The usual focusing range is from +2 to −4 diopters.

You will find several different types of eyepieces in the various marks of Navy rangefinders.



148.19

Figure 4-14.—Principle of the coincidence prism.

The following are the two most common:

1. The orthoscopic eyepiece, composed of a cemented triplet and a single lens.
2. The achromatic eyepiece, composed of two cemented doublets with an air space between them. Newer instruments are provided almost exclusively with the achromatic eyepiece.

Astigmatizers

Two astigmatizers—one in each telescope—are mounted on the objective side of the coincidence prism. You can throw them simultaneously to the IN position, where they intercept the rays just before they reach the coincidence prism; or to the OUT position, out of the line of sight, where they have no effect on the image.

Each astigmatizer is actually a cylindrical lens with its surface ground to a cylindrical, rather than a spherical shape. A cylindrical lens produces an elongated image so that the image of a single point appears as a line. Astigmatizers are useful when you are ranging on a searchlight at night. Here your target image is practically a point of light. You would have to manipulate the rangefinder carefully to get that point image exactly on the halving line. Even then you could never be sure you had made exact coincidence. However, when you throw the astigmatizers to the IN position, the two half-images of the searchlight become vertical lines of light perpendicular to the halving line (see figure 4-15). To make exact

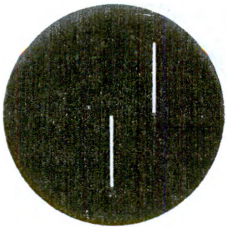


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Figure 4-15.—Astigmatized half-images of a searchlight.

coincidence, you need only turn the ranging knob until the two half-images form a single, unbroken vertical line.

Color Filters

The color filters are mounted between the coincidence prism and the eyepiece. They come in various colors in the various marks of rangefinders. Filters serve to dim brilliant images, reduce haze, and, under some conditions, increase the contrast of a target against its background.

RANGEFINDER MK 21 MOD 2

The Rangefinder Mk 21 Mod 2, (figure 4-16), is a portable, 1-meter base, coincidence-type instrument used primarily for navigation. It is a 14-power instrument designed to measure ranges between 250 and 10,000 yards.

In use, it may be handheld, mounted in a socket, or supported in a web harness worn by the operator.

The Mk 21 has two eyepieces, one for ranging and one for reading the range scale.

Range Scale Reading System

The left eyepiece is used to read the range scale. It consists of a window and dove prism, which allow you to read the indicator range with the left eye, and a lamp, filter, and condenser lens, which illuminate the range scale (figure 4-17). A scale reader prism is incorporated to provide a magnified view of the scale.

The range scale (figure 4-18) is engraved with graduations indicating 5-yard intervals from 250 to 500 yards; 10-yard intervals from 510 to 1,000 yards; 50-yard intervals from 2,100 to 5,000 yards; 500-yard intervals from 5,500 to 10,000 yards; and 500-yard intervals from 15,000 to 20,000 yards. An asterisk marks the infinity graduation with 3 graduations on either side to indicate units of error (uoe) short of or beyond infinity.

Main Optical System

The main optical system (figure 4-19) consists of end windows, penta prisms, astigmatizers, objectives, a range wedge, a coincidence prism, ray filters, and an eyepiece. The various components function as described previously. The exception is the left end window, which is an

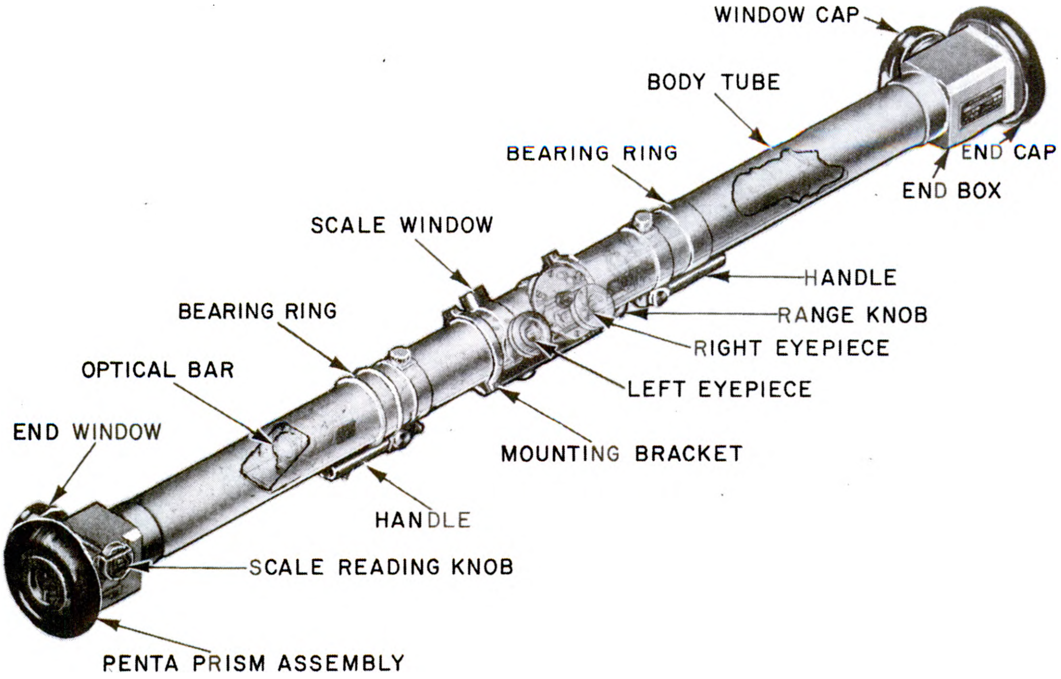

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Figure 4-16.—Location of rangefinder components.

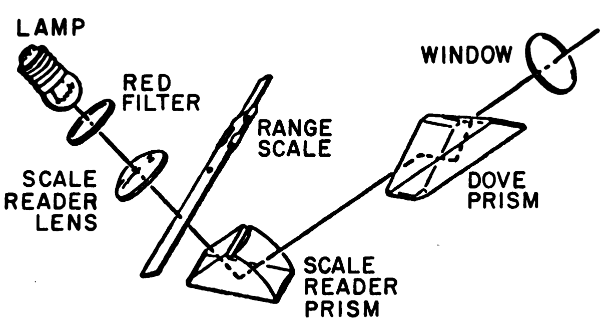

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Figure 4-17.—Range scale reader optical system.

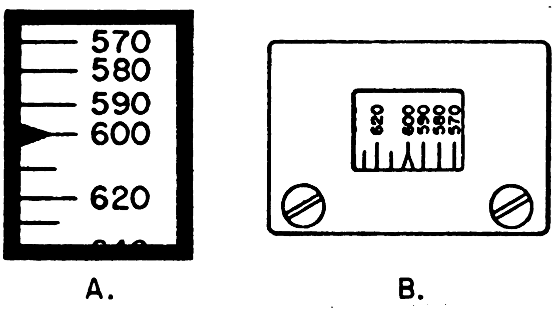

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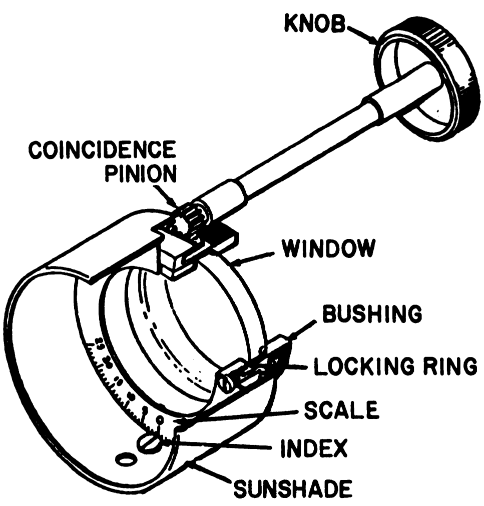
Figure 4-18.—Views of range scale.

optical wedge; it deviates the line of sight 1.5 minutes and is mounted in a rotatable bushing. The left end window (figure 4-20) can be adjusted to provide coincidence when the rangefinder is sighted on a target of known range with the range scale set for that range.



148.334

Figure 4-20.—Left end windows.

The penta prism mounts are adjustable to remove target lean and halving error. The objectives are adjustable to remove parallax, and the coincidence prism can be moved to make the halving lines coincident.

RANGEFINDER OPERATION

The primary job of the rangefinder operators is to measure ranges accurately, consistently, and with reasonable speed. To do this job successfully, they must have a thorough knowledge of rangefinder adjustments, and continued practice in making them. The Opticalman's primary job is to repair the rangefinder—not to operate it. But the OM can do his job more efficiently by

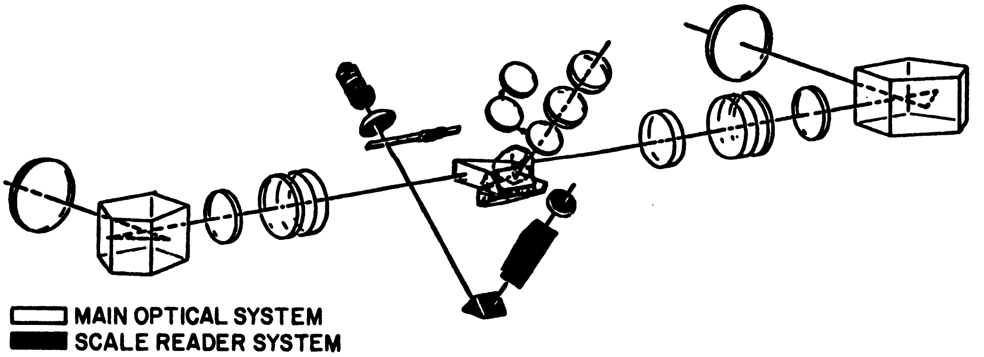


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Figure 4-19.—Rangefinder optical systems.

becoming thoroughly familiar with the operating technique and by developing maximum skill as a rangefinder operator. Here are some tips on the rangefinder operation:

Do not spend too much time on one range setting. If you make a setting carefully and confidently, it will probably be accurate. If you make a setting hesitantly and then back off a little and try again, it may not be as accurate.

The range setting can be made in two ways: (1) By making the original setting too long, and then turning back to the target; (2) by making the original setting too short, and then working forward to the target. If possible, use the second method, setting the original range short and working toward the target. At longer ranges this method can provide a more accurate range setting.

On stationary or slow-moving targets, always make the setting in the same direction, whether measuring ranges or calibrating the rangefinder. A fast-moving target, on the other hand, can be tracked more smoothly when the settings are made in the direction of target motion.

In most respects, the operation of the coincidence and stereoscopic rangefinders is similar. To operate the coincidence type of rangefinder, you should make the following adjustments:

1. Set the focus.
2. Check the halving adjustment and readjust if necessary.
3. Make all internal adjustments. Use the median correction.
4. Use a filter if visibility is poor.
5. If ranging on a point of light at night, turn the astigmatizers to the *in* position.

These adjustments are the same as those for a stereoscopic rangefinder except for the halving adjustment and the use of astigmatizers.

The *halving adjustment* is needed to secure the proper alignment of the two half-images so that the operator sees a single unbroken image without duplication or deficiency (figure 4-21).

In making the halving adjustment, select a target with a small and clearly defined top and of a shape that will not "telescope" easily. (A pyramid or diagonal is most useful; avoid a mast or other vertical structure.) Use the elevation control to move the halving line slowly up and down over the top of the target. Look closely for any duplication or deficiency.

Be sure that, unless you are ranging on a point of light at night, the *astigmatizers* are out. If they are in, they will give you a blurred and streaky image and make ranging impossible.

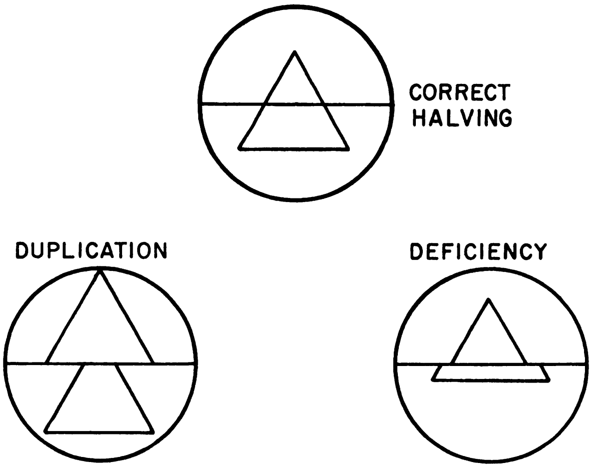

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Figure 4-21.—Effects of duplication and deficiency.

RANGEFINDER INSPECTION

Rangefinders must be inspected regularly to keep defects from developing unnoticed. Check rangefinders frequently to ensure the following conditions:

1. Cleanliness of exposed optical surfaces
2. Supply of lens tissue at the rangefinder station
3. Cleanliness of eye guards
4. Lubrication of mount
5. Helium purity (in antiaircraft rangefinders)

With a few obvious exceptions, such as interpupillary distance setting, the inspection tests just described will apply equally well to the coincidence rangefinder. The following tests apply to the coincidence type only.

ASTIGMATIZERS

With the astigmatizers out, range on a slender, vertical target that makes good contrast against its background. Then range on the same target with the astigmatizers in. The two readings should be the same.

HALVING

Turn the halving adjuster knob through its entire travel and count the turns; then turn back half way. The instrument should be approximately in the halving position. Roll the rangefinder in its bearings and then recheck the halving adjustment.

LEAN

Range on a target at the right-hand side of the field and make a careful halving adjustment. Swing the rangefinder in azimuth to bring the target to the left-hand side of the field. The halving adjustment should still be correct.

COMPENSATOR SETTING

Range on a target near the minimum range and make a careful halving adjustment. Then range on a target near the maximum range. The halving adjustment should remain correct. (You need not know the true range of the two targets.)

RANGEFINDER CALIBRATION

Complete and accurate calibration data for each rangefinder in service is essential. Correct gun elevation depends primarily on correct measurement of the target range. If the rangefinder readings are inaccurate, the initial salvos will be off in both range and deflection (since drift varies with range). Subsequent analyses of firings may lead to erroneous or conflicting conclusions. Before you can rely on a rangefinder for accurate measurements, you must calibrate it by comparing its readings with other measurements of known accuracy. (The internal adjustment cannot serve the purpose of a complete calibration, since it checks the range scale at only one specified range.)

Although rangefinders are calibrated at assembly and after each overhaul, their calibration should be checked at every opportunity. Errors can develop from a slight shift of the end windows (this is rather rare) or of the optical parts of the internal adjuster system or main optical system. They can also be caused by personal errors of individual operators.

To correct for the constant errors (range error and UOE) found in a rangefinder, you must first determine an appropriate offset of the correction scale (called calibration offset or index correction). Then you must apply it to the correction scale after the internal adjustment. Next you must make a preliminary calibration of the rangefinder by adjusting its end windows. Fine calibration for each individual operator must be made by applying the calibration offset to the correction scale. Should you find that all the operators of a particular rangefinder require fairly large calibration offsets in the same direction, readjust the end windows.

The instrument should be completely recalibrated following repairs that involve a major optical part between the end windows and the reticles of a stereo rangefinder. It should also be recalibrated following repairs that involve a major optical part between the end windows and coincidence prism of a coincidence rangefinder.

If the rangefinder is properly adjusted, a single calibration offset (for one particular operator) will be good at all ranges. Under certain atmospheric conditions you may get long or short readings at different ranges. These effects are mostly small and are too insignificant to be considered. If a rangefinder has two magnifications, you can use the same calibration offset for both. Always use the highest magnification when you are calibrating the instrument.

When you calibrate a rangefinder, keep these points in mind:

1. Rangefinder errors increase as the square of the range increases. For that reason, calibration errors that appear insignificant at short range will become serious at long range.
2. When you calibrate a rangefinder against a known range, the probable error of the known range must be considerably less than the probable error of the rangefinder. If the known range has been measured from some point other than the rangefinder you are calibrating, do not forget to apply a suitable correction.
3. Besides the theoretical error, other factors limit the accuracy of the rangefinder: heat waves, range rate, vibration, variations in target contrast, and so forth.
4. Rangefinders are more accurate at high magnification. An instrument that provides a choice of magnification should be calibrated at its highest power.
5. After a sudden change in temperature, wait several hours before you begin calibration. When you are going to calibrate a turret rangefinder in a gun director, turn on the turret blowers several hours ahead of time.

6. Variations in the density of the gas inside the instrument (called stratification) will cause some inaccuracy in ranges of overhead targets. (This effect is very small when helium is used as the charging gas.)

7. Because of the limitations of lens design, rangefinders are more accurate at the center of the field than at its edges.

CALIBRATION ON FIXED TARGETS

The simplest way to calibrate a rangefinder is by calibrating on fixed targets. Range on a fixed target at a known distance. By comparing the scale reading with the known distance, you can determine the rangefinder error at that range.

You can sometimes use radar to range on a radar beacon. Alongside each radar beacon is a visible marker that makes a convenient target for the rangefinder. This method is most useful at long ranges.

For calibrating on any fixed target, proceed as follows:

1. Make all preliminary adjustments carefully. Make at least five internal adjustments and record the median correction.
2. Set the range scale at the known range of the fixed target.
3. Range on the target with the correction knob and record the settings.
4. If the range scale is properly calibrated, there will be no difference between the median of the settings on the fixed target and the median of the settings on the internal target of the rangefinder.

If stationed at a naval shipyard, you should be able to pick out a few easily recognizable objects for use as ranging standards. Use the ground plane of the yard to determine the distance of those objects from the optical shop. If stationed on a repair ship, you should either be able to find fixed markers suitable for ranging or establish your own markers.

If necessary you can use the sun, the moon, or a star as a fixed target by setting the range scale at infinity. You can use the moon either during the day or at night. You can use the sun if the rangefinder has searchlight filters. If you use stars you will have to make very accurate height adjustments. These procedures are useful only when observing conditions are good and the operators are experienced. Experiments show that when inexperienced operators range on an infinity target, they get about three times the spread of readings that they get on targets at a finite distance.

RANGEFINDER MAINTENANCE

Because of its size, a rangefinder looks like a rugged piece of gear. Actually it is a delicate instrument that must be handled with care. When you overhaul it, you must align the elements within extremely small tolerances. It will take careful handling of the rangefinder to preserve your delicate adjustments. No one should be permitted to touch a rangefinder except qualified operators and qualified Opticalmen.

To allow the operator to handle the instrument gently, make sure that all the knobs and levers can be turned smoothly without jerking or forcing them. The internal parts of the instrument normally require no lubrication except during a complete overhaul. To keep oil and oil vapor from reaching the lenses, apply lubricant very sparingly to the parts that extend into the rangefinder. Check the rangefinder mounts regularly and frequently, and lubricate them whenever necessary.

As much as possible, protect the rangefinder from bad weather. Put canvas boots or metal covers over the end boxes of turret rangefinders. Cover all exposed instruments to protect them from rain and spray. If a rangefinder is unavoidably or accidentally exposed to rain or spray, clean it thoroughly and promptly. Take off its covers in good weather to keep moisture from condensing inside. Protect the optical elements from direct sunlight. Sunlight ages the glass and cement and introduces temporary inaccuracy because of unequal heating.

Clean a rangefinder the same way you would clean a big telescope. Wipe the body with a clean, dry cloth. Gently remove any grit or salt from the outside optical surface with a clean camel's hair brush. Finally, polish the surface with lens tissue. If there is grease on the surfaces, add a drop or two of alcohol to the tissue.

Experienced rangefinder personnel will be able to find the cause of any minor difficulty and correct it. Less experienced operators will probably depend on you for help. Here is a list of minor rangefinder troubles that you should be able to recognize and correct.

1. Bulbs loose, burned out, or in wrong receptacles

2. Rheostat turned too low
3. Range scale set at wrong range during internal adjustment
4. Adjuster knob turned only partly into position
5. Reticle lights on when you make internal adjustments
6. Change-of-magnification knob between two positions
7. Color filters part way in
8. Neutral or polaroid filter unintentionally turned in
9. Height adjustment incorrect
10. Astigmatizers turned in
11. Searchlight filter in

COLLIMATION OF THE MK 21

The initial collimation of the Mk 21 is performed during overhaul. The left end window, range wedge, and astigmatizers are collimated individually before being assembled in the optical tube. The optical tube, with its ranging optics, is collimated as a unit. The penta prisms are adjusted during reassembly.

RANGE WEDGE

The range wedge must be collimated so that its plane of deviation of light is in the plane of triangulation (the plane formed by the line of sight of each telescope and the target (figure 4-22)).

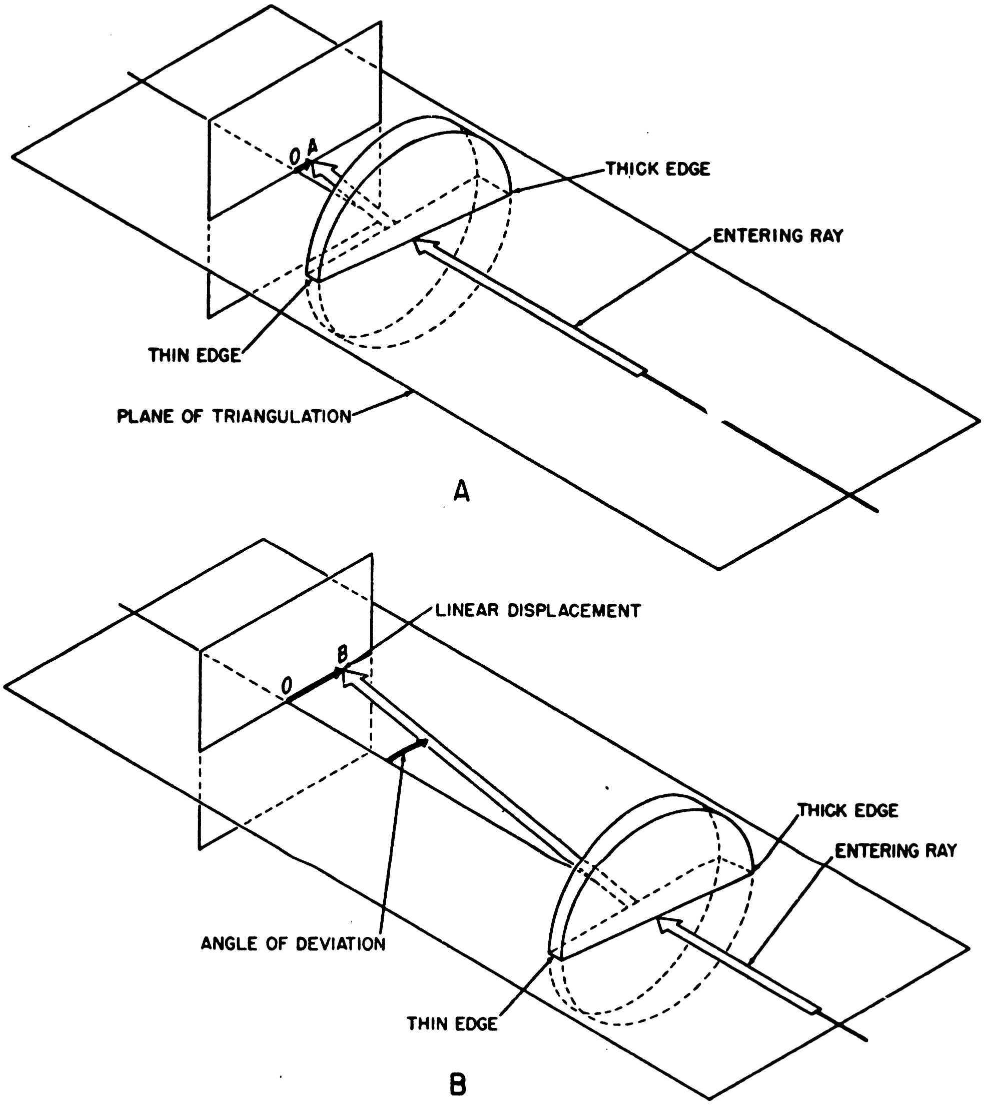

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Figure 4-22.—Displacement produced by a sliding wedge.

During the collimation of the correction wedge, the crosslines of both telescopes must be squared to the collimator bed and superimposed. Install the range wedge assembly on parallel bars with the rack down and the cell adjusting screws facing the boresight telescope.

The first step in collimation is to adjust the rack parallel to the line of sight of the collimator telescope and boresight telescope. Using an auxiliary objective and a machinist's square, alternately set the edge of the square to each end of the rack. If the edge of the square is superimposed on the vertical crossline of the boresight, when moved to either end of the rack, the rack is parallel to the telescope's line of sight.

Rotate the wedge cell until the horizontal crosslines of both telescopes are superimposed and the vertical crossline of the boresight telescope is to the right of the collimator telescope's vertical crossline.

Left End Window

Mount the left end window bushing assembly (figure 4-23), with the left end window installed, in a V-block support on the collimator. The two screw holes in the bushing must be perpendicular to the collimator bed. Use the auxiliary objective to align the screwholes with the vertical crossline of the boresight.

Rotate the end window until both telescope horizontal crosslines are superimposed, and the vertical crosslines are parallel. Mark the cell bushing with a pencil to indicate the base of the wedge. The collimator telescope vertical crossline will be deviated toward the base of the wedge. Look through the boresight. You will see that the collimator telescope vertical crossline will be offset from the boresight vertical crossline toward the base of the wedge.

Install the end window scale on the end window bushing with the O position of the scale adjacent to the base of the wedge.

Astigmatizers

The astigmatizers (figure 4-24) must be adjusted so that the elongation of the image they produce is perpendicular to the plane of triangulation. To adjust, install one astigmatizer between the collimator and boresight telescopes in an upside down position. The plano surface of the astigmatizer lens should be approximately perpendicular to the line of sight. Do this by aligning the astigmatizer lens mount so that it is perpendicular to the lateral edge of the collimator bed and the horizontal (top) surface of the bed.

Tape a pinhole diaphragm over the collimator telescope to provide a point source of light. Viewing through the boresight telescope, rotate the astigmatizer lens until the line of light, produced by the astigmatizer, is parallel to the vertical crossline of the boresight telescope.

Repeat the alignment process for the second astigmatizer lens.

OPTICAL TUBE

The optical tube (figure 4-25), with its components installed, is collimated so that the target images are in coincidence when the image scale is set at infinity. Place the assembled optical tube between two prealigned collimator

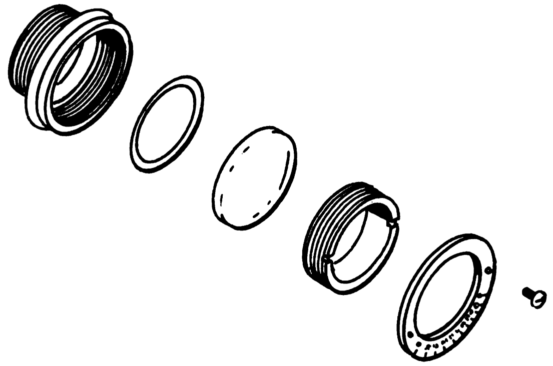

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Figure 4-23.—Left window bushing assembly.

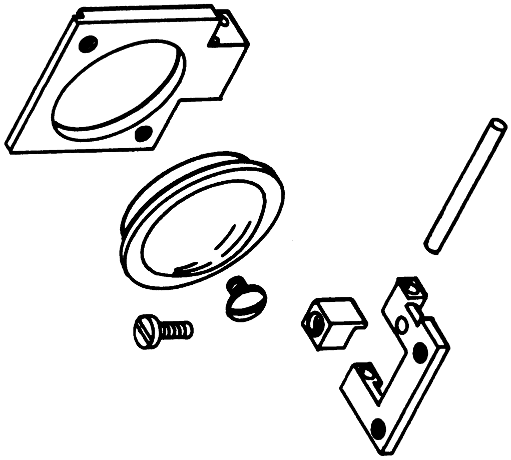

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Figure 4-24.—Astigmatizer mount assembly.

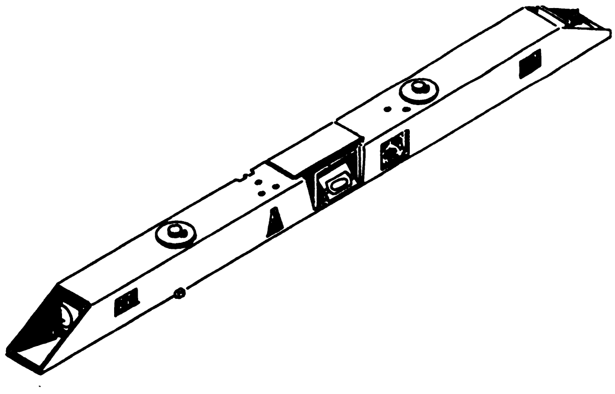

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Figure 4-25.—Optical tube.

telescopes. The astigmatizers should be in the out position. Position an auxiliary eyepiece over the coincidence prism so that the halving line is in sharp focus.

PARALLAX

The first step in removing parallax is to set the range scale to infinity. Then adjust each objective cell to bring its corresponding crossline image into sharp focus.

HALVING LINE COINCIDENCE

The coincidence prism mount must be adjusted so that the halving lines are in coincidence. Loosen the center (hold down) screw and adjust the positioning screws for coincidence of the halving lines.

The astigmatizers must be adjusted to maintain coincidence of the halving lines when the astigmatizers are shifted into the line of sight. Shift the astigmatizers into the line of sight. If the halving lines are not in coincidence, adjust the astigmatizer mount that has offset either of the halving lines.

COLLIMATION OF ASSEMBLED MK 21

Before installing the sealing caps and end plates, you must remove target lean and height error, if present.

Target lean is checked on the horizon with the rangefinder in a level position. When the rangefinder is rotated to shift the horizon above and below the halving line, the horizon should be parallel to the halving line both above and below it. Keep in mind that the upper half of the image is formed by the left side of the rangefinder.

To remove lean from either side, adjust its penta prism assembly. The post (figures 4-26 and 4-27) may be screwed in or out as required to remove lean.

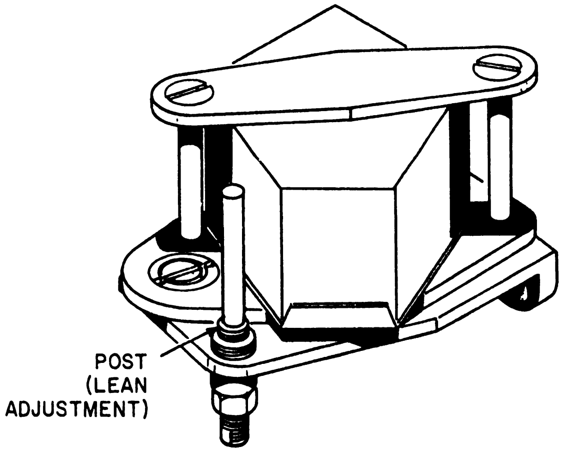

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Figure 4-26.—Left penta prism assembly.

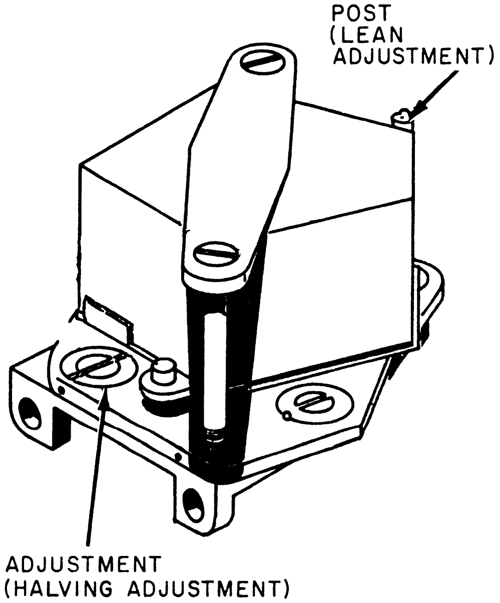

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Figure 4-27.—Right penta prism assembly.

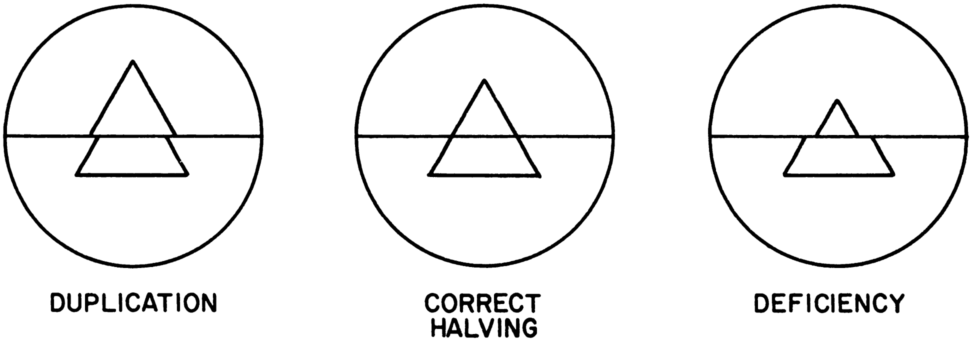

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Figure 4-28.—Halving adjustment.

Height error (or halving error) exists when duplication deficiency is present, as shown in figure 4-28. This error is caused by one or both of the prisms being rotated so that they are not in a plane that is 43° to the line of sight of the eyepiece. To remove duplication or deficiency, set the halving knob at midthrow and make the screw adjustment under the 90° corner of the right penta prism (figure 4-27). Complete procedures for overhaul, collimation of the Mk 21 rangefinder are found in OP 2147.

DRYING AND CHARGING RANGEFINDERS

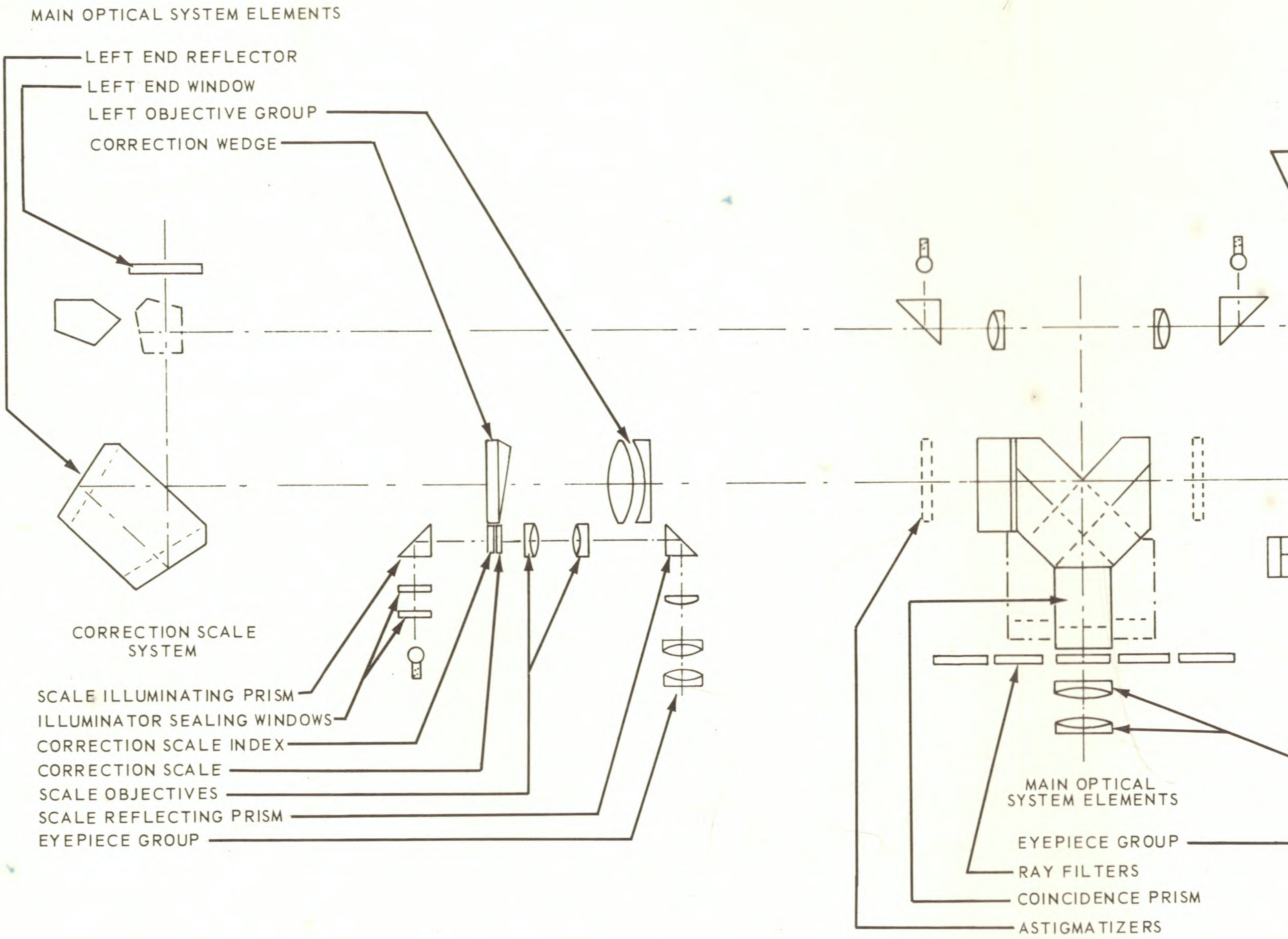
The primary purpose of charging is to keep moisture from condensing on the optical surfaces; the secondary purpose is to protect the optical elements from the aging effect of oxygen. In charging a rangefinder you must pass compressed gas from a cylinder, through a pressure-reducing valve and a dryer, into the instrument. Before the final charging, dry the instrument thoroughly either by flushing it with dry gas or by repeatedly drawing a vacuum of about 22 inches.

The Navy uses two different gases for rangefinder charging: nitrogen and helium. Nitrogen has one marked disadvantage: it tends to stratify into layers of different indices of refraction. When you elevate the instrument to range on aircraft, light rays will be refracted in passing from one layer of nitrogen to another, thus causing a small error in range setting. For this reason, antiaircraft rangefinders are always charged with helium, which has much less tendency to stratify.

Since helium molecules are considerably smaller than those of nitrogen, helium has a greater tendency to leak. The gas purity of helium-filled instruments should be checked every two weeks. You can use a special helium-purity gage for this purpose. If the gage is not available, you can check the helium purity by making two internal adjustments—one when the rangefinder is level and one when it is elevated 90°. There will always be a difference between the two settings. But if you make the check every two weeks and find that the difference suddenly increases, you can assume that the helium is no longer pure.

Some instruments are designed for helium, others for nitrogen. Always charge an instrument with the gas it is designed for. Helium and nitrogen have different indices of refraction. You know that refraction in an optical element depends on the ratio of its index of refraction to that of the surrounding atmosphere. If you put one gas in an instrument designed for another, you will change the optical characteristics of the whole system. On instruments designed for helium, the charging nipples are always painted orange or yellow.

Optical instruments should be recharged every 12 months with dry gas. It is much harder to dry out a damp instrument than it is to keep moisture from condensing in the first place. When an instrument shows any sign of condensation on an internal surface, *recharge it at once*. Complete gasing procedures, are described in NAVEDTRA 10205-C, *Opticalman 3 & 2*.


MAIN OPTICAL SYSTEM ELEMENTS
LEFT END REFLECTOR
LEFT END WINDOW
LEFT OBJECTIVE GROUP
CORRECTION WEDGE
CORRECTION SCALE SYSTEM
SCALE ILLUMINATING PRISM
ILLUMINATOR SEALING WINDOWS
CORRECTION SCALE INDEX
CORRECTION SCALE
SCALE OBJECTIVES
SCALE REFLECTING PRISM
EYEPIECE GROUP
MAIN OPTICAL SYSTEM ELEMENTS
EYEPIECE GROUP
RAY FILTERS
COINCIDENCE PRISM
ASTIGMATIZERS

CHAPTER 5

MIRCS LABORATORIES

When you become a Chief Opticalman, you may become responsible for the operation and the personnel in the Mechanical Instrument Repair and Calibration Shop (MIRCS). As you advance to pay grade E-9 where the OM and IM ratings combine to PICM, you must become more familiar with the operations of the MIRCS. This chapter will cover the broad mission of the MIRCS installation and describe some of its capabilities.

THE NAVY METROLOGY AND CALIBRATION (METCAL) PROGRAM

Metrology is the science and art of measurement for the determination of conformance to technical requirements. It includes the development of standards and systems for absolute and relative measurements. It also includes calibration.

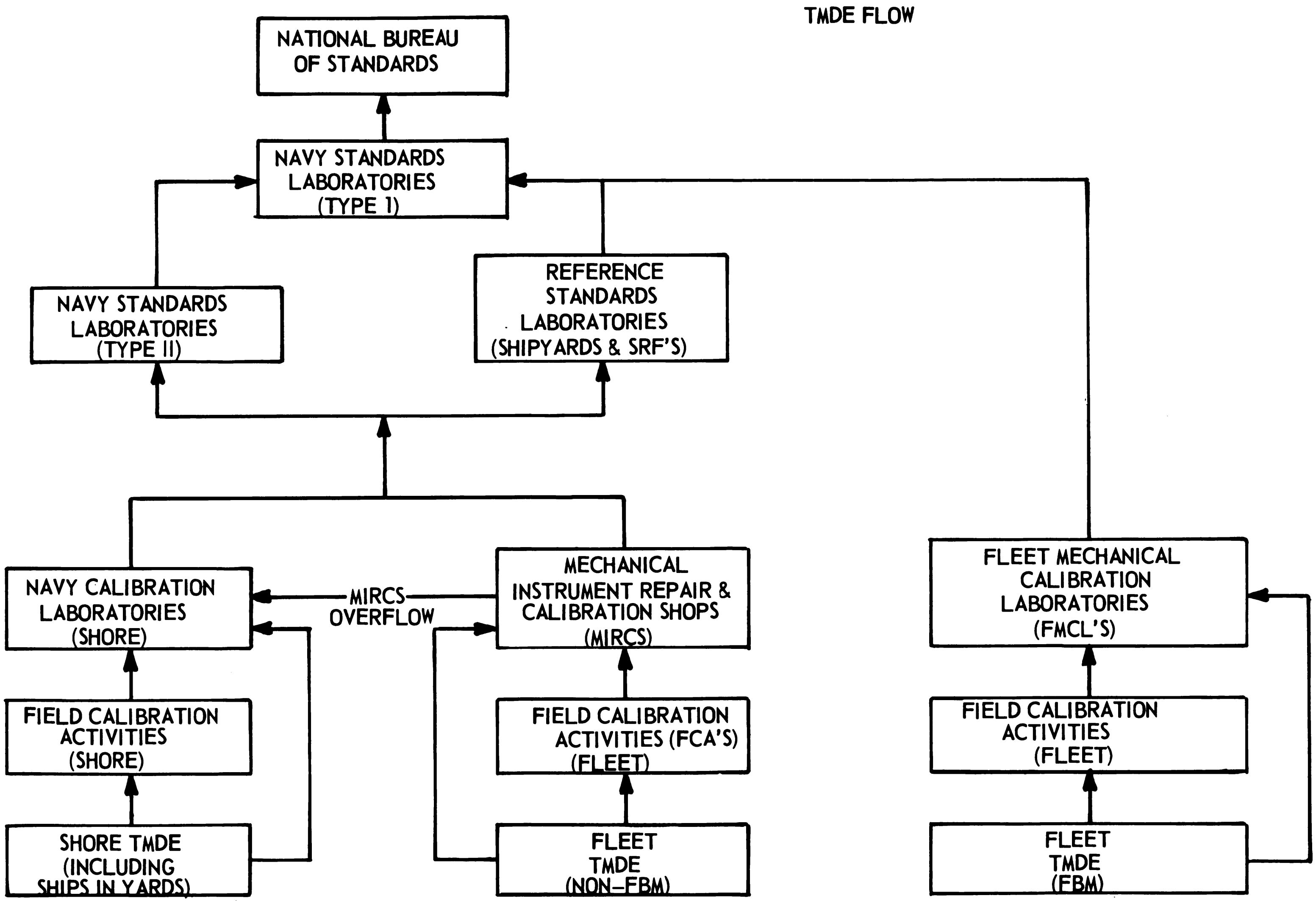
Calibration assures us that our weapons systems are working right and that the parts obtained from different manufacturers will fit together as they should. The success of our Navy depends on the use of accurate and reliable measuring instruments. The best way to assure continued accuracy is by periodic calibration performed by skilled technicians.

The increased complexity of ship systems (especially weapons, propulsion, and navigation) has made it necessary to improve the quality and accuracy of measurements. Formerly, problems existed in measurements because the measurements of one activity did not agree with those of another activity even though identical items were being measured. In those cases, activities tended to *write off* the discrepancies as variations in the measuring instrument. But, in fact, most of the discrepancies resulted from the lack of standardized measurements. The Navy Calibration Program was established for the purpose of standardizing instrument measurements. This program emphasizes the need for complete measurement standardization throughout the Navy.

The calibration of all measuring devices is based on, and is dependent upon, the basic international and national standards of measurement. However, we cannot rush off to the National Bureau of Standards every time we need to measure a length, a mass, a weight, or an interval of time. Consequently, the National Bureau of Standards (NBS) prepares and issues a great many practical standards that can be used by government and industry to calibrate their instruments. Government and industry, in turn, prepare their own standards, which are applicable to their own requirements. Refer to figure 5-1 for a heirarchy breakdown of authority levels from on-site to NBS. Thus a continuous linkage of measurement standards exists beginning with the international standards, through the national standards, down to the rulers, weights, clocks, gages, and other devices that we use for everyday measurement.

The Navy has established the METCAL program to ensure traceability and accuracy of instrument calibration to the NBS. To operating personnel, this means that any instrument used aboard ship for quantitative measurement must be calibrated and that the standards used are more accurate than the shipboard instruments. The accuracy of a standard must be traceable, through documentation by each higher calibration activity, to the NBS. Each instrument that is calibrated (including standards) must bear evidence that it is in calibration. This evidence is provided in the form of a calibration label affixed to the instrument. This label provides the date and place of calibration and the next due date for calibration.

The METCAL program provides for periodic calibration of most instruments. The responsibility for assignment of these periodic calibration intervals has been given to the Metrology Engineering Center (MEC).


TMDE FLOW
NATIONAL BUREAU OF STANDARDS
NAVY STANDARDS LABORATORIES (TYPE 1)
NAVY STANDARDS LABORATORIES (TYPE II)
REFERENCE STANDARDS LABORATORIES (SHIPYARDS & SRF'S)
NAVY CALIBRATION LABORATORIES (SHORE)
MIRCS OVERFLOW
MECHANICAL INSTRUMENT REPAIR & CALIBRATION SHOPS (MIRCS)
FLEET MECHANICAL CALIBRATION LABORATORIES (FMCL'S)
FIELD CALIBRATION ACTIVITIES (SHORE)
FIELD CALIBRATION ACTIVITIES (FCA'S) (FLEET)
FIELD CALIBRATION ACTIVITIES (FLEET)
SHORE TMDE (INCLUDING SHIPS IN YARDS)
FLEET TMDE (NON–FBM)
FLEET TMDE (FBM)

148.437

Figure 5-1.—Heirarchy breakdown.

CALIBRATION

Calibration is the act of comparing a measurement system or device of unverified accuracy to a measurement system or device of known and greater accuracy to detect and correct any variation from required performance specifications.

STANDARD

A standard is a laboratory-type device used to maintain continuity of value in the units of measurement. Its accuracy is ensured through periodic comparison with higher echelon or national standards. A standard may be used either to calibrate a standard of lesser accuracy or to calibrate test and measurement equipment directly.

TRACEABILITY

Traceability is the unbroken chain of properly conducted and documented calibration of equipment from the fleet through higher echelons to the NBS.

MECHANICAL INSTRUMENT REPAIR AND CALIBRATION SHOPS (MIRCS)

MIRCS are facilities located on board tenders (other than FBM), repair ships, and specified shore activities. Their function is to calibrate and repair test and monitoring systems (TAMS) installed aboard ships and submarines.

FLEET MECHANICAL CALIBRATION LABORATORIES (FMCLs)

FMCLs are calibration laboratories located on board FBM submarine tenders. They provide calibration services for both tender and FBM submarine mechanical, test, and measurement equipment. The FMCLs are operated by IM or OM personnel with an 1821 NEC. The basic difference between the MIRCS and the FMCL is that the FMCL has the additional capability for optical calibration.

CALIBRATION PUBLICATIONS, FORMS, AND LABELS

The metrology program uses many publications, forms, and labels needed to operate the program efficiently and effectively. This chapter will identify and discuss the major publications, forms, and labels related to the calibration program.

METROLOGY REQUIREMENTS LIST (METRL)

The METRL is an authoritative reference document published by MEC and updated semiannually. It contains several separate sections. They are (1) General, (2) Generic Calibration Intervals, (3) Test and Monitoring Systems (TAMS) Calibration Requirements, (4) Calibration Procedures, and (5) Calibration Related Documents.

METROLOGY BULLETIN

The Metrology Bulletin is a monthly official publication issued by MEC. This bulletin contains updated calibration intervals, newly issued procedures and changes to already published procedures, and answers to problem referrals from fleet activities. The Metrology Bulletin can be a very useful tool because it provides interim information prior to its incorporation in the METRL.

METER CARD

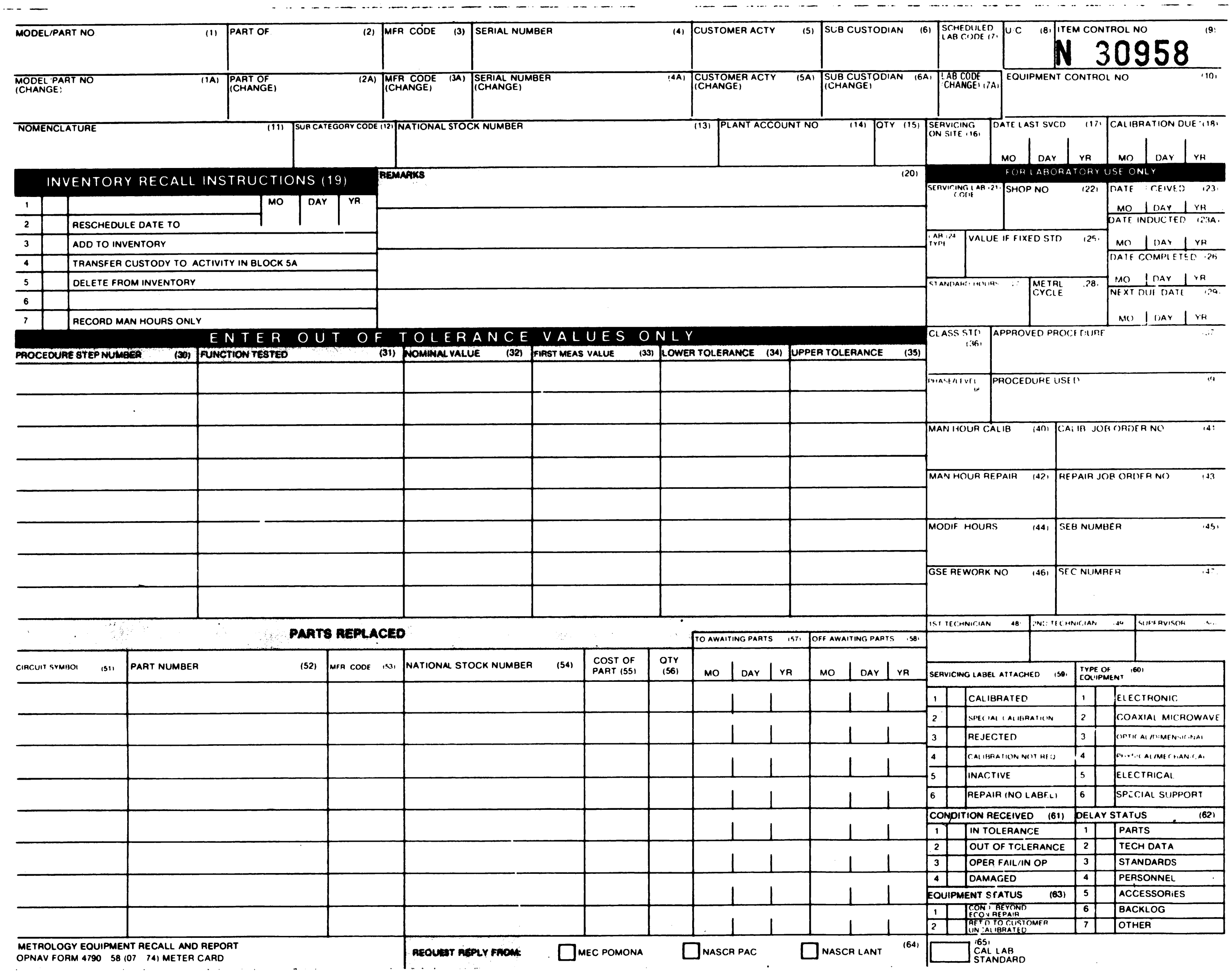
The METER card (fig. 5-2) is a five-part, color-coded form to which the Equipment Identification and Receipt Tag (fig. 5-3) is attached. It is filled out by either the customer or the calibrating activity. It is used to report information and transactions pertaining to TAMS and calibration standards.

CALIBRATED LABEL

The calibrated label (black lettering, white background) (fig. 5-4) which comes in three different sizes, is the most commonly used label in the METCAL program. It identifies an instrument that is within its applicable tolerance on all parameters.

INACTIVE LABEL

If an individual instrument due for recalibration is not expected to be used for some time in the future, you may postpone the recalibration indefinitely by affixing an Inactive label (green lettering, white background) to the instrument.



MODEL/PART NO (1) | PART OF (2) | MFR CODE (3) | SERIAL NUMBER (4) | CUSTOMER ACTY (5) | SUB CUSTODIAN (6) | SCHEDULED LAB CODE (7) | U C (8) | ITEM CONTROL NO (9) N 30958

MODEL PART NO (CHANGE) (1A) | PART OF (CHANGE) (2A) | MFR CODE (CHANGE) (3A) | SERIAL NUMBER (CHANGE) (4A) | CUSTOMER ACTY (CHANGE) (5A) | SUB CUSTODIAN (CHANGE) (6A) | LAB CODE CHANGE (7A) | EQUIPMENT CONTROL NO (10)

NOMENCLATURE (11) | SUB CATEGORY CODE (12) | NATIONAL STOCK NUMBER (13) | PLANT ACCOUNT NO (14) | QTY (15) | SERVICING ON SITE (16) | DATE LAST SVCD (17) MO DAY YR | CALIBRATION DUE (18) MO DAY YR

INVENTORY RECALL INSTRUCTIONS (19)

			MO	DAY	YR
1	☐				
2	☐	RESCHEDULE DATE TO			
3	☐	ADD TO INVENTORY			
4	☐	TRANSFER CUSTODY TO ACTIVITY IN BLOCK 5A			
5	☐	DELETE FROM INVENTORY			
6	☐				
7	☐	RECORD MAN HOURS ONLY			

REMARKS (20)

FOR LABORATORY USE ONLY

SERVICING LAB CODE (21) | SHOP NO (22) | DATE RECEIVED (23) MO DAY YR

DATE INDUCTED (23A) MO DAY YR

LAB TYPE (24) | VALUE IF FIXED STD (25)

DATE COMPLETED (26) MO DAY YR

STANDARD HOURS (27) | METRL CYCLE (28) | NEXT DUE DATE (29) MO DAY YR

ENTER OUT OF TOLERANCE VALUES ONLY

PROCEDURE STEP NUMBER (30)	FUNCTION TESTED (31)	NOMINAL VALUE (32)	FIRST MEAS VALUE (33)	LOWER TOLERANCE (34)	UPPER TOLERANCE (35)

CLASS STD (36) | APPROVED PROCEDURE (37)

PHASE/LEVEL (38) | PROCEDURE USED (39)

MAN HOUR CALIB (40) | CALIB JOB ORDER NO (41)

MAN HOUR REPAIR (42) | REPAIR JOB ORDER NO (43)

MODIF HOURS (44) | SEB NUMBER (45)

GSE REWORK NO (46) | SEC NUMBER (47)

1ST TECHNICIAN (48) | 2ND TECHNICIAN (49) | SUPERVISOR (50)

PARTS REPLACED

CIRCUIT SYMBOL (51)	PART NUMBER (52)	MFR CODE (53)	NATIONAL STOCK NUMBER (54)	COST OF PART (55)	QTY (56)	TO AWAITING PARTS (57) MO	DAY	YR	OFF AWAITING PARTS (58) MO	DAY	YR

SERVICING LABEL ATTACHED (59)			TYPE OF EQUIPMENT (60)		
1	☐	CALIBRATED	1	☐	ELECTRONIC
2	☐	SPECIAL CALIBRATION	2	☐	COAXIAL MICROWAVE
3	☐	REJECTED	3	☐	OPTICAL/DIMENSIONAL
4	☐	CALIBRATION NOT REQ	4	☐	PHYSICAL/MECHANICAL
5	☐	INACTIVE	5	☐	ELECTRICAL
6	☐	REPAIR (NO LABEL)	6	☐	SPECIAL SUPPORT
CONDITION RECEIVED (61)			DELAY STATUS (62)		
1	☐	IN TOLERANCE	1	☐	PARTS
2	☐	OUT OF TOLERANCE	2	☐	TECH DATA
3	☐	OPER FAIL/IN OP	3	☐	STANDARDS
4	☐	DAMAGED	4	☐	PERSONNEL
EQUIPMENT STATUS (63)			5	☐	ACCESSORIES
1	☐	COND BEYOND ECON REPAIR	6	☐	BACKLOG
2	☐	RET'D TO CUSTOMER UNCALIBRATED	7	☐	OTHER

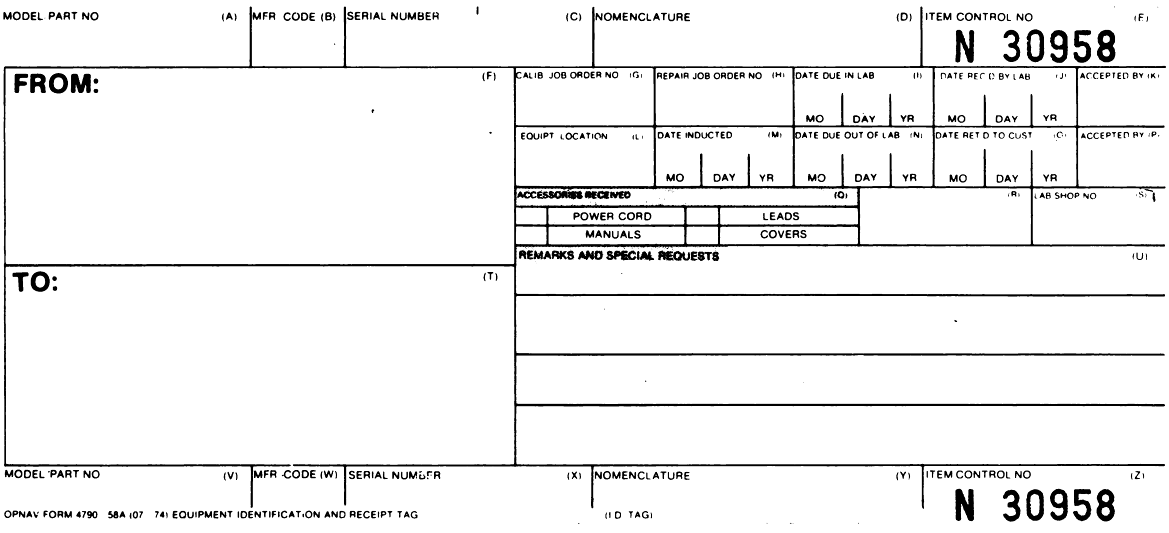
METROLOGY EQUIPMENT RECALL AND REPORT
OPNAV FORM 4790 58 (07 74) METER CARD

REQUEST REPLY FROM: ☐ MEC POMONA ☐ NASCR PAC ☐ NASCR LANT (64)

☐ (65) CAL LAB STANDARD

148.438

Figure 5-2.—Meter card.



MODEL PART NO (A) | MFR CODE (B) | SERIAL NUMBER (C) | NOMENCLATURE (D) | ITEM CONTROL NO (E) **N 30958**

FROM: (F)

CALIB JOB ORDER NO (G) | REPAIR JOB ORDER NO (H) | DATE DUE IN LAB (I) MO DAY YR | DATE REC'D BY LAB (J) MO DAY YR | ACCEPTED BY (K)

EQUIPT LOCATION (L) | DATE INDUCTED (M) MO DAY YR | DATE DUE OUT OF LAB (N) MO DAY YR | DATE RET'D TO CUST (O) MO DAY YR | ACCEPTED BY (P)

ACCESSORIES RECEIVED (Q) | (R) | LAB SHOP NO (S)

	POWER CORD		LEADS
	MANUALS		COVERS

REMARKS AND SPECIAL REQUESTS (U)

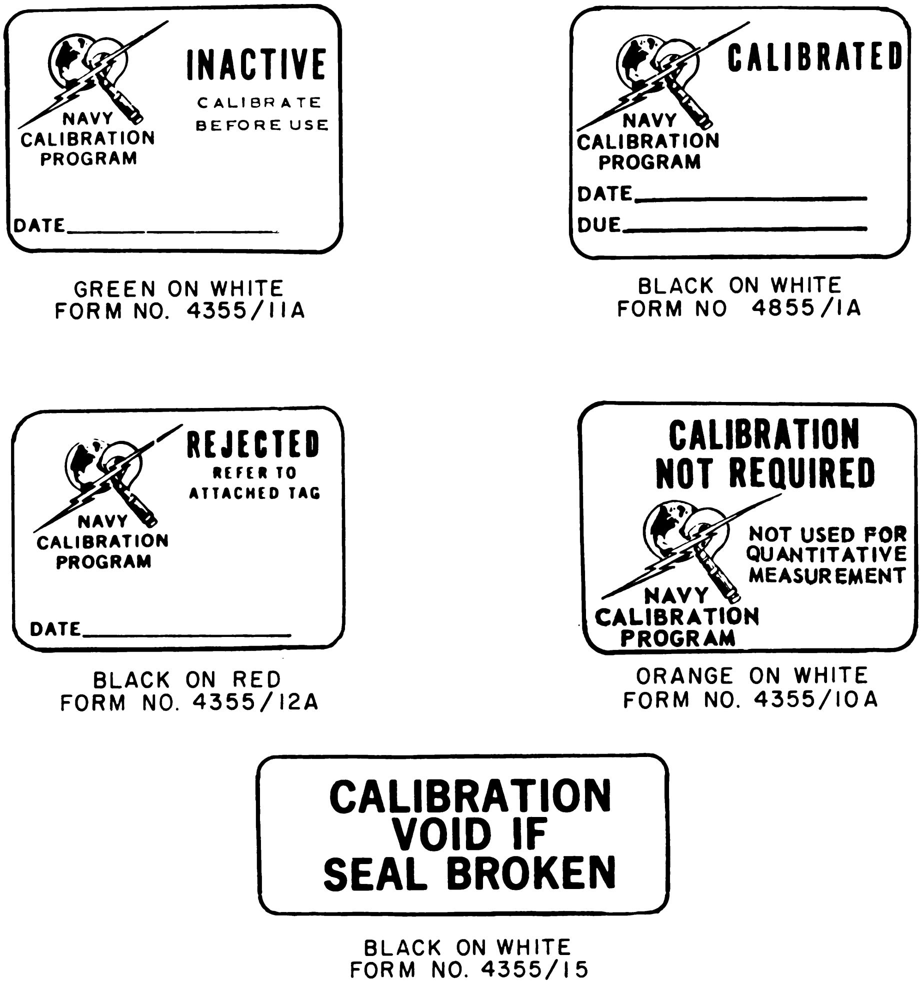
TO: (T)

MODEL PART NO (V) | MFR CODE (W) | SERIAL NUMBER (X) | NOMENCLATURE (Y) | ITEM CONTROL NO (Z) **N 30958**

OPNAV FORM 4790 58A (07 74) EQUIPMENT IDENTIFICATION AND RECEIPT TAG (I D TAG)

148.439

Figure 5-3.—Equipment identification and receipt tag.



GREEN ON WHITE
FORM NO. 4355/11A

BLACK ON WHITE
FORM NO 4855/1A

BLACK ON RED
FORM NO. 4355/12A

ORANGE ON WHITE
FORM NO. 4355/10A

BLACK ON WHITE
FORM NO. 4355/15

173.6

Figure 5-4.—Calibration labels.

The Inactive label (fig. 5-4) remains on the instrument until the instrument is recalibrated. An instrument may not be used while bearing the Inactive label. It must be calibrated before it can be used.

CALIBRATION NOT REQUIRED LABEL

Standards and TAMS not requiring calibration are shown as NCR in the METRL. The Calibration Not Required label (orange letters, white background) (fig. 5-4) is affixed to and should remain on the instrument until its calibration requirements change.

When an instrument falls into the Calibration Not Required category, the label must be annotated as to the authority on which the decision was based, such as METRL, technical manual, letter, or message from higher authority. In the case of instruments that normally require periodic calibration but are not used to perform quantitative measurements, the label should bear the notation "Not Used for Quantitative Measurements."

REJECTED LABEL

In the event an instrument fails to meet the acceptance criteria during calibration and cannot be adequately repaired, a Rejected label (black lettering, red background) (fig. 5-4) must be placed on the instrument. All other servicing labels must be removed. In addition to the Rejected label, a Rejected tag giving the reason for rejection and any other pertinent information is affixed to the instrument. The Rejected label and tag remain on the instrument until it is repaired and recalibrated. The instrument *must not* be used while bearing a Rejected label.

CALIBRATION VOID IF SEAL BROKEN LABEL

The Calibration Void If Seal Broken label (black lettering, white background) (fig. 5-4) is placed over readily accessible (usually exterior) adjustments to prevent tampering by the user when such tampering could affect the calibration. This label must not cover any adjustments or controls that are part of the normal use and operation of the instrument. The Calibration Void If Seal Broken label is also used to prevent removal and/or interchange of plug-in modules, subassemblies, and so forth, when such removal or interchange can affect the calibration.

PROCEDURAL STANDARDIZATION

Calibrations performed by different activities can be identical only if the methods used to perform the calibrations are the same for all activities. The MEC has the responsibility for procedural standardization within the calibration program.

Prior to performing calibration of any instrument, the technician must review the appropriate calibration procedure listed in the METRL. This publication lists authorized procedures by equipment and model number. The approved procedures section of this publication provides information about changes and indicates the dates when the revisions were made.

MIRCS CAPABILITIES

As mentioned at the beginning of this chapter, you must also become familiar with the capabilities of the various test standards provided by the MIRCS facility. You must remember that all labs are not the same, and capabilities do vary between labs.

PRESSURE AREAS

MIRCS have two types of pressure calibration areas—low and high. These laboratories are equipped with test stands and work areas.

Low Pressure

In the low-pressure area you can test vacuum gauges from 0 to 30 inches of mercury, pressures from 0 to 400 inches of water, and pressure gauges from 0 to 100 pounds per square inch (psi).

High Pressure

In the high-pressure area you can normally test gauges with ranges between 100 psi and 10,000 psi. This includes pneumatic hydraulics gauges.

PORTABLE PRESSURE TESTERS

MIRCS also use portable pressure testers that cover a variety of ranges up to 10,000 psi. These testers are used for on-site calibration.

TORQUE TESTERS

Testers to measure torque are also available. Three ranges of torque testers are used. These are capable of testing from 0 to 500 oz-in., from 0 to 2,000 lb-in. and from 0 to 1,000 lb-ft.

TACHOMETER CALIBRATION

Stroboscope discs or digital counters are used to calibrate tachometers. Their range is from 36 revolutions per minute (rpm) to 10,000 rpm in increments of 50, 100, 200, or 400 rpm.

TEMPERATURE CALIBRATION

Three baths are used in the temperature calibration area. A low bath, which is used on calibrations from −40° to 200°F; a medium bath for calibrations from ambient temperature to 500°F; and a high bath for calibrations from 400° to 1,000°F.

DIMENSIONAL

Dimensional calibration is the calibration of precision linear measurement instruments such as inside/outside micrometers, vernier calipers, and electronic height gauges.

FLOW

Calibrations of flow meters and rotameters are used to measure liquids such as water and low viscosity fuels.

MERCURY

Calibration of mercury medium filled instruments, as well as clean up of mercury spills by MIRCS personnel cleanup team, must be accomplished in accordance with NAVSEAINST 5300.3.

OXYGEN

Cleaning, repairing, and calibrating instruments used in oxygen service systems are most commonly done on submarine tenders only.

To gain a fuller knowledge of the equipment in a MIRCS and its testing capabilities, you should read *IM 3 & 2*, NAVEDTRA 10193-D and complete the NRCC. Additionally obtain NAVMATINST 4355.67 and NAVSEA instruction 4855.9.

CHAPTER 6

SUBMARINE PERISCOPES I

In spite of the many advances in submarine detection devices (radar, sonar, and ESM), the periscope is still the submerged submarine's primary tool for the location, identification, and reconnaissance of surface and airborne targets. When it is submerged, the submarine also depends primarily on the periscope for navigational information.

This chapter will introduce you to submarine periscope maintenance.

Before you start work on a particular periscope or any advanced optical system, however, be sure to refer to the appropriate technical manual.

IDENTIFICATION OF PERISCOPES

Three common methods for identifying periscopes are as follows: design designation, registry number, and type number. The first two methods are discussed in *Opticalman 3 & 2*.

TYPE NUMBERS

The type number of any periscope refers to its general design characteristics. It is assigned by NAVSEA. Numbers are assigned consecutively, beginning with type 1, an obsolete attack periscope, through type 18, a highly advanced, multipurpose periscope.

Certain periscopes have acquired both number and letter designations. For example, the type 2A is a modification of the type 2 that was used extensively during and after World War II. Today, submarines are being outfitted with attack types 2D, 2E, or 2F.

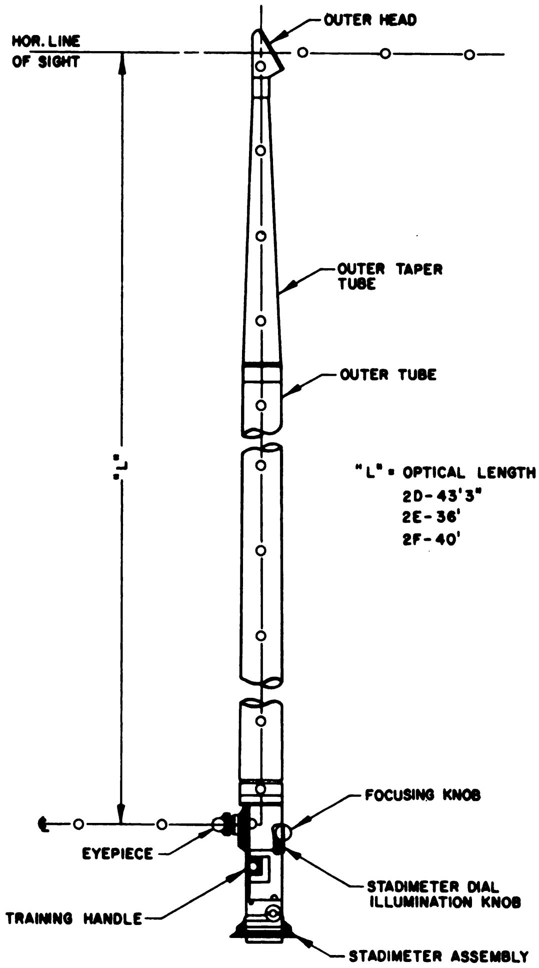
These periscopes have the same operational configurations and are used for the same purposes as the old type 2.

Design designations are seldom used in discussions of periscopes. The type number is usually used to identify a particular periscope except in the case of two installed periscopes which are referred to as No. 1 and No. 2 according to their position within the submarine.

Many types of periscopes have been manufactured. Some were designed for particular and unusual needs. Characteristics of different type number periscopes are described below.

- Type 1—This was the forerunner of the modern attack periscope. It has a stadimeter for estimating range and course angle.

- Type 2—This is still the attack periscope of the modern submarine. Although the older types 2 and 2A differ greatly from the newer 2D, 2E, and 2F types (fig. 6-1), all attack periscopes have range-measuring devices incorporated in



134.101

Figure 6-1.—Attack periscope.

their optical systems and the capability of elevating the line of sight to at least 74° above the horizon. The 2D, 2E, and 2F types are built to withstand greater seawater pressures to which they are subjected.

- Type 3—This now obsolete attack periscope was capable of elevating the line of sight 45° above the horizon.

- Type 4—This is the forerunner of all general-purpose periscopes. It was designed with a large head section for greater light transmission and had a radar capability.

- Type 5—This was a special-purpose instrument designed primarily for photographic reconnaissance, now obsolete.

- Type 6—This was an unusual submarine periscope, now obsolete. The type 6, with its modifications, was an any-height instrument which the observer could use at any height between the top of the sail and the fully extended position. The observer always faced forward while using the instrument. As the rotating portion of the instrument rotated, an internal erecting system provided the observer with an erect image and an indicator showed what direction the line of sight was pointing.

- Type 7—This was the forerunner of the modern navigation periscope, now obsolete. It was the first night periscope to incorporate synchros into its elevation system.

- Type 8—This is the first of a series of periscopes incorporating the features of the types 4 and 7. Types 8 and 8A were superseded by the more modern 8B and the similar, but shorter, 8C which are more versatile and sophisticated than their predecessors.

- Type 9—This was designed as a night service instrument with celestial navigation capabilities. The type 9, now obsolete, was the forerunner of the type 11.

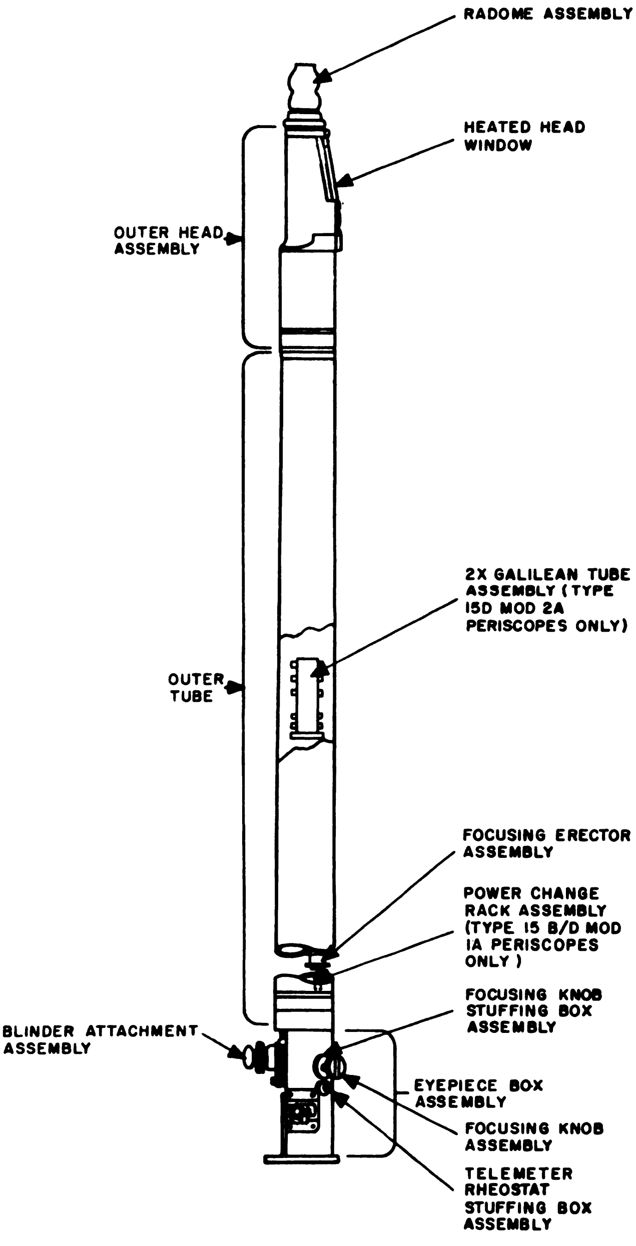
- Type 10—This is an experimental design of a navigational periscope, now obsolete. It incorporated a photoelectric cell to control the line of sight.

- Type 11—This was a special-purpose celestial navigation instrument designed for fleet ballistic missile (FBM) submarines. It provides correction information for the ship's gyroscope compass and Sperry Inertial Navigation System (SINS).

- Type 12 and Type 13—These type numbers were assigned to designs which were never manufactured.

- Type 14.—This was a special-purpose deep submergence attack periscope. Internally it is similiar to the type 2D. The type 14 has telemeter illumination and an optical length of 28 feet.

- Type 15.—This was designed to increase the electronic capabilities of the type 8B, type


RADOME ASSEMBLY
HEATED HEAD WINDOW
OUTER HEAD ASSEMBLY
2X GALILEAN TUBE ASSEMBLY (TYPE 15D MOD 2A PERISCOPES ONLY)
OUTER TUBE
FOCUSING ERECTOR ASSEMBLY
POWER CHANGE RACK ASSEMBLY (TYPE 15 B/D MOD 1A PERISCOPES ONLY)
FOCUSING KNOB STUFFING BOX ASSEMBLY
BLINDER ATTACHMENT ASSEMBLY
EYEPIECE BOX ASSEMBLY
FOCUSING KNOB ASSEMBLY
TELEMETER RHEOSTAT STUFFING BOX ASSEMBLY

148.440

Figure 6-2.—Type 15 periscope.

Table 6-1.—Type 15 Periscope Modifications

Types 15 B & D Mod 1A Periscope ESM Package	1. Increased sensitivity in omnidirectional antenna, by using a voltage probe antenna (VPA) packaged within the main radome assembly (This will reduce the possibility of flooding.)
Type 15D Mod 2A Periscope Modification	1. Periscope modified for 12X magnification by means of changes to head skeleton, inner tube sections, and eyepiece box 2. Wire heated head window installed instead of tin-oxide coated window 3. Universal heated head window control box installed instead of existing heated head window control box

15 periscope, and its modifications use an optical system similar to that of the 8B. It is now replacing the 8B as the general-purpose periscope of today's submarine forces.

Most of the periscopes in use in the fleet today are type 15D periscopes (fig. 6-2). In this chapter, we will discuss the 15D generation of periscopes, pointing out the features peculiar to the attack and general-purpose types. For security reasons, the ECM and communications systems will not be discussed.

Type 15B Mod 1A, type 15D Mod 1A, and type 15D Mod 2A periscope sets have been brought to their configurations by a series of field and factory changes. These modifications are described in table 6-1.

- Type 16—This is a highly specialized periscope not being used widely throughout the fleet at this time. It incorporates more sophisticated electronic and photographic equipment than those which are presently used by other types. The handling, repair, and installation of this type of periscope is done by the OM under supervision of the technical representatives of the manufacturer. The manuals required for any work to be done are hand carried to the unit by the manufacturer's representative.

- Type 17—This type of number is assigned to a design which was never manufactured.

- Type 18—This is a highly versatile, multipurpose instrument that has virtually replaced the type 15 periscope as the general-purpose periscope in today's modern Navy. Its major capabilities are as follows:

1. Multiple levels of magnification.
2. Power assisted training operation.
3. Gyro stabilized optics (including photography).
4. Image motion compensated photography.
5. Image intensification for low light level operation. (Night vision).
6. Television system, capable of monitoring all optical modes. Includes VCR/VTR.
7. Target bearing transmission.
8. A broad spectrum of RF intercept capabilities.

PERISCOPE SYSTEMS

The major systems for which you will have maintenance responsibility include the elevation, power change, focusing, ranging, optical, maintenance, and electrical systems. Most periscopes are alike in their elevation, focusing, or power change systems. Their ranging systems, however, are peculiar to the attack series of the type 2 generation. The entire 15D generation has electrical maintenance requirements, but only those with navigational capabilities have synchro alignment requirements.

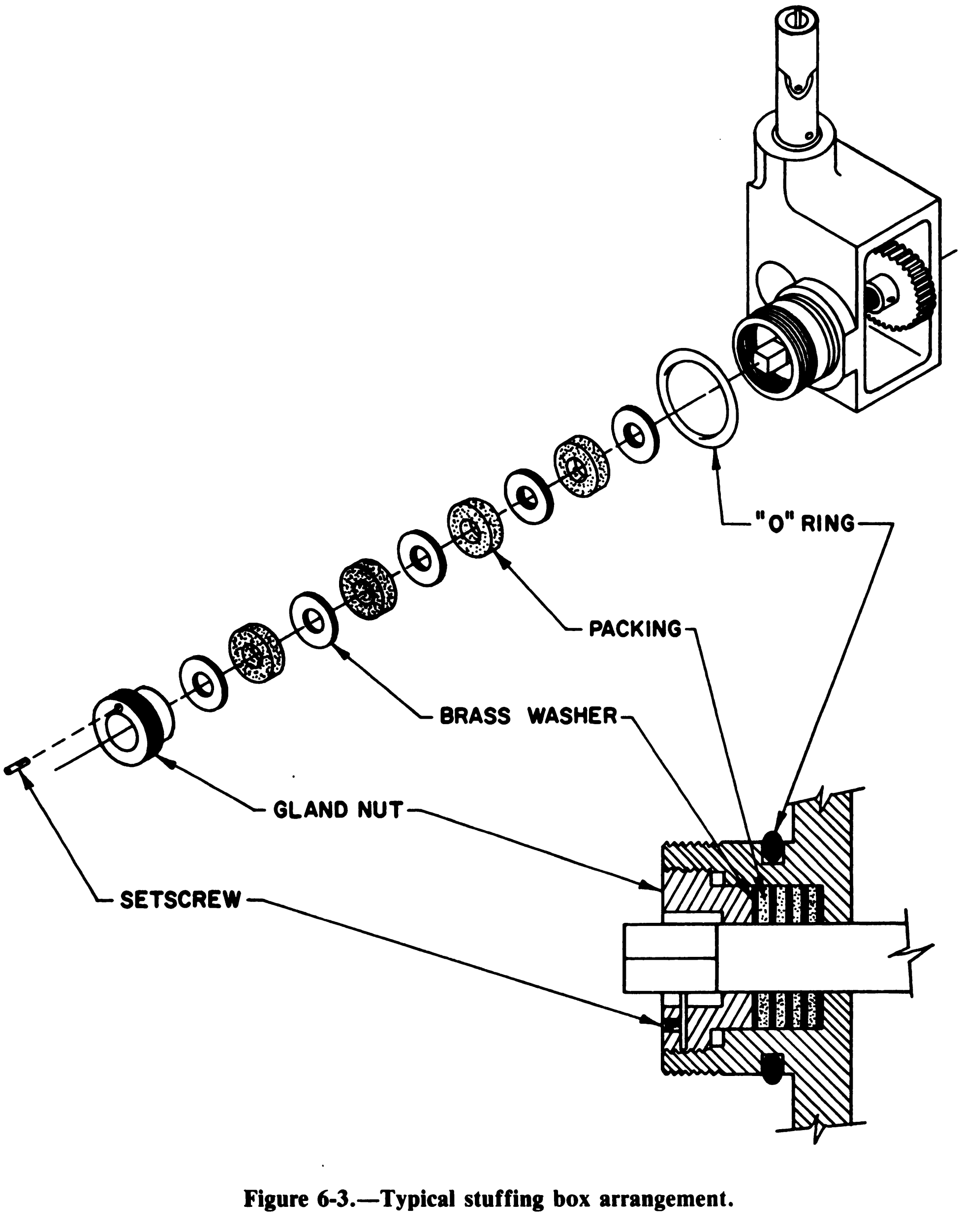
All these systems are operated from outside the periscope through some form of penetration which must maintain the hermetical seal of the periscope itself. Stuffing boxes enable motion to be transmitted from outside the periscope and maintain the hermetical seal.

The stuffing boxes (fig. 6-3) are used on all rotating shafts such as elevation, focus, power change, rheostat, and stadimeter. They seal against the loss of internal pressure and, should the periscope develop a leak, the entrance of seawater into the submarine. All internal electrical systems penetrate the periscope through pressure-tight receptacles.

ELEVATION SYSTEM

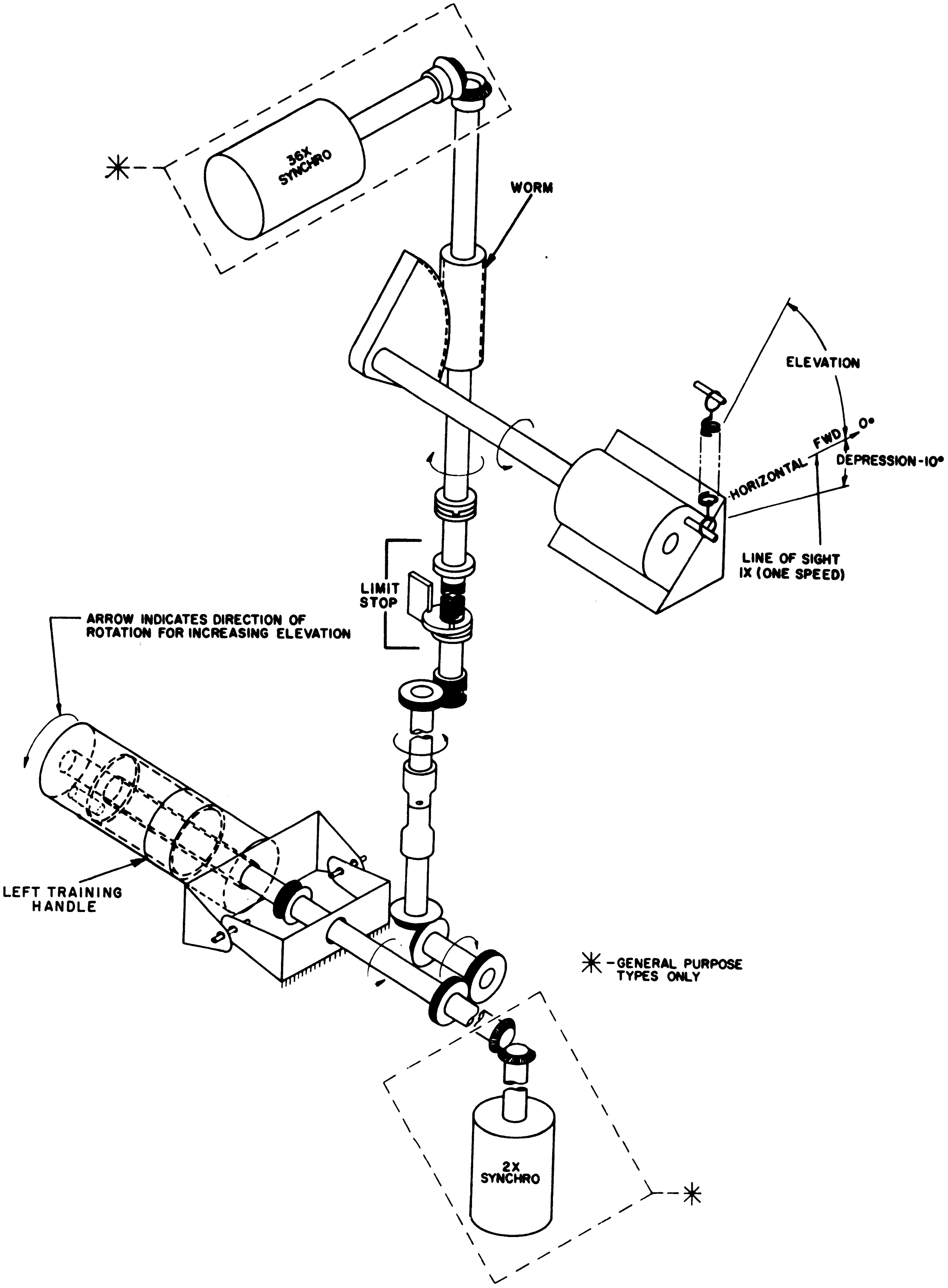
The primary function of the elevation system of a submarine periscope is to elevate or depress the line of sight as desired by the observer. A secondary function (in the general-purpose types only) is to transmit elevation information electrically for celestial navigation.

The elevation systems (fig. 6-4) are similar for all periscopes. Synchros apply only to



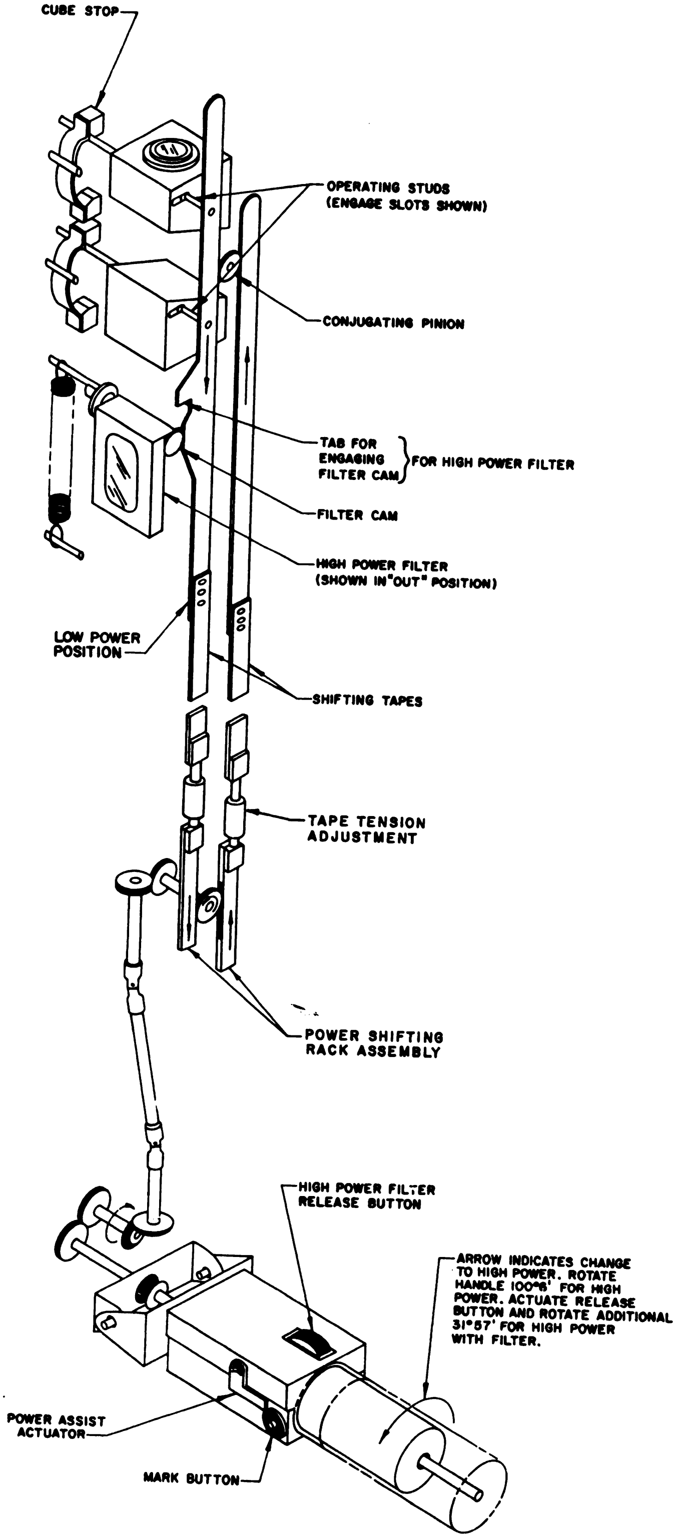
28.35

Figure 6-3.—Typical stuffing box arrangement.



148.281

Figure 6-4.—Elevation system.


CUBE STOP
OPERATING STUDS (ENGAGE SLOTS SHOWN)
CONJUGATING PINION
TAB FOR ENGAGING FILTER CAM } FOR HIGH POWER FILTER
FILTER CAM
HIGH POWER FILTER (SHOWN IN "OUT" POSITION)
LOW POWER POSITION
SHIFTING TAPES
TAPE TENSION ADJUSTMENT
POWER SHIFTING RACK ASSEMBLY
HIGH POWER FILTER RELEASE BUTTON
ARROW INDICATES CHANGE TO HIGH POWER. ROTATE HANDLE 100°6' FOR HIGH POWER. ACTUATE RELEASE BUTTON AND ROTATE ADDITIONAL 31°57' FOR HIGH POWER WITH FILTER.
POWER ASSIST ACTUATOR
MARK BUTTON

148.347

Figure 6-5.—Change of power system.

general-purpose types. The left-training handle controls the elevation or depression of the line of sight. The top of the handle is turned toward the observer to elevate the line of sight. The line of sight is depressed when the top of the training handle is turned away from the observer.

The motion of the training handle is transmitted through a stuffing box, a series of gears and shafts, and finally to the head prism where it is converted into elevation or depression of the line of sight.

On the attack periscopes, a 4° rotation of the training handle corresponds to a 1° elevation of the line of sight.

On general-purpose periscopes, elevating the line of sight is sensed by two synchros that feed the elevation information to celestial navigation equipment. A 5° rotation of the training handle corresponds to a 1° elevation of the line of sight, which corresponds to a 36° rotation of the 36X (upper) synchro rotor and a 2° rotation of the 2X (lower) synchro rotor.

CHANGE OF POWER SYSTEM

As discussed in *Opticalman 3 & 2*, the method of changing the power of the periscope is to insert or remove a one-fourth power telescope into the line of sight. This is the primary function of the change of power system (fig. 6-5). The power is changed by rotation of the right-training handle (as discussed in *Opticalman 3 & 2*). Additionally, the change of power system of general-purpose periscopes places a sun filter into the line of sight when desired by the observer. The right-training handle of a general-purpose type has features not incorporated in the right-training handle of an attack periscope.

The sun filter, for example, is placed into the line of sight by pushing the filter release button towards the periscope and rotating the handle beyond the HIGH-POWER position to the FILTER position. The periscope is always in high power when the sun filter is in the line of sight. When you are removing the filter from the line of sight, the filter release button is pushed toward the periscope, and the handle is rotated to either the HIGH-POWER or LOW-POWER position.

Another feature, the power assist actuator, is used to energize a power assist motor for torquing in the direction that the observer desires. When the periscope is being used for celestial navigation, the sextant mark button provides a means for the observer to indicate that the crosslines are superimposed on the target.

The motion of the training handle is transmitted through a stuffing box and through a gear-and-shaft system to the power change rack assembly.

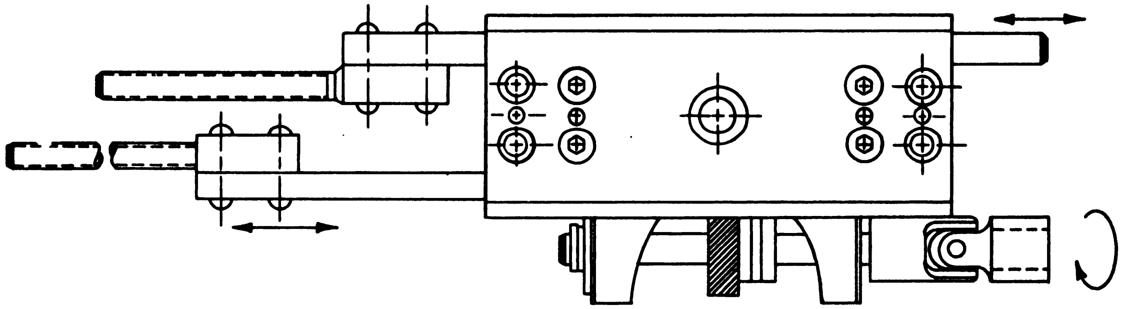
The power change rack assembly (fig. 6-6) converts the rotary movement of the handle into a linear movement of the shifting tapes.

The shifting tapes and the power shifting racks move the power change cubes into and out of the line of sight. The power change cubes contain the elements of the one-fourth power telescope which provides the periscope change of power.

NOTE: Type 15D Mod 2A periscope sets are equipped with a power change shaft instead of the power change rack and associated tapes while the type 18 periscope changes magnification through electrical drive motors.

FOCUSING SYSTEM

The various types of periscopes have similar focusing systems (fig. 6-6). The system functions to vary the focus between + 1.5 and − 3 diopters



148.349

Figure 6-6.—Power change rack assembly.

for normal viewing and to move the focusing erector (and its focal point) approximately 203.2 mm towards the eyepiece for photographic purposes. Total movement of focusing erector is 210.89 mm. When the focusing erector is shifted to the photographic position, its focal point is located outside of the eyepiece sealing window. The type 18 periscope system contains three separate focusing systems. One system focuses the optics in the mast, one focuses the optics in the eye box, and one automatically focuses the camera from infinity to 200 yards.

The focusing knob (as discussed in *OM 3 & 2*) contains a stop mechanism, engaged by the plunger, which limits the focusing knob travel between +1.5 and −3 diopters for normal viewing. When the photographic position is desired, the plunger is withdrawn and locked in the OUT position that allows the focusing knob to be turned in a minus diopter direction until the camera stop position is reached.

The focusing knob motion is transmitted through a stuffing box and gear-and-shaft arrangement to the focusing erector assembly. This assembly contains a planetary gear arrangement (fig. 6-7) that turns three shafts simultaneously to move the focusing erector laterally along the line of sight.

RANGING SYSTEM

The ranging system of the attack periscopes (fig. 6-8) provides a means for determining target range when target height is known. There are two operating controls on the stadimeter. The in-out lever shifts the split lens into and out of the line of sight. The range knob displaces vertically the two identical images produced by the split lens.

The range-indicating mechanism is composed of three rings located at the base of the stadimeter. The lower ring is fixed and has graduations indicating target height in feet. The middle ring is manually rotated and has one index on its lower edge that must be set to the desired target height. The upper edge of the middle ring has two index marks: HP (for high power) and LP (for low power). These marks indicate the target range corresponding to the target height set for the power in use. The target range, read on the upper ring (in yards), is interconnected to the split lens assembly.

OPTICAL SYSTEM

The periscopes of the type 2, 8, and 15 generations have similar optical systems. It is convenient to discuss and to point out significant differences where they occur.

Characteristics

The various types of periscopes of the type 2, 8, 15, and 18 series have the following optical characteristics in common:

	High Power	Low Power
Magnification	6X	1.5X
Model 2A also has	12X	
True field	8°	32°
Depression of line of sight	−10°	−10°
Maximum Elevation		
Line of Sight		
Attack	74°	74°
General Purpose	60°	60°
Edge of Field		
Attack	78°	90°
General Purpose	64°	76°
Type 18 periscope	3X	1.5X
	6X	
	12X	
	24X	
Focus Range	−3 to +1.5 diopters for normal viewing; approximately −203.2 mm for the camera focus.	

The exit pupil of the attack periscope type 2 is 5 mm when used in the viewing mode and 4.18 mm when used in the range-finding mode with the split lens in the line of sight. The exit pupil of the general-purpose types (8 and 15) is 7 mm.

Although the function of the various elements within the periscopes is basically the same (to transmit the image through the periscope to the observer), the design of the type 2, 8, and 15 generations differs from their predecessors. The concept of an upper and lower main telescope and an upper and lower auxilliary telescope, as discussed in *Opticalman 3 & 2*, has been superseded by a single telescope containing relay

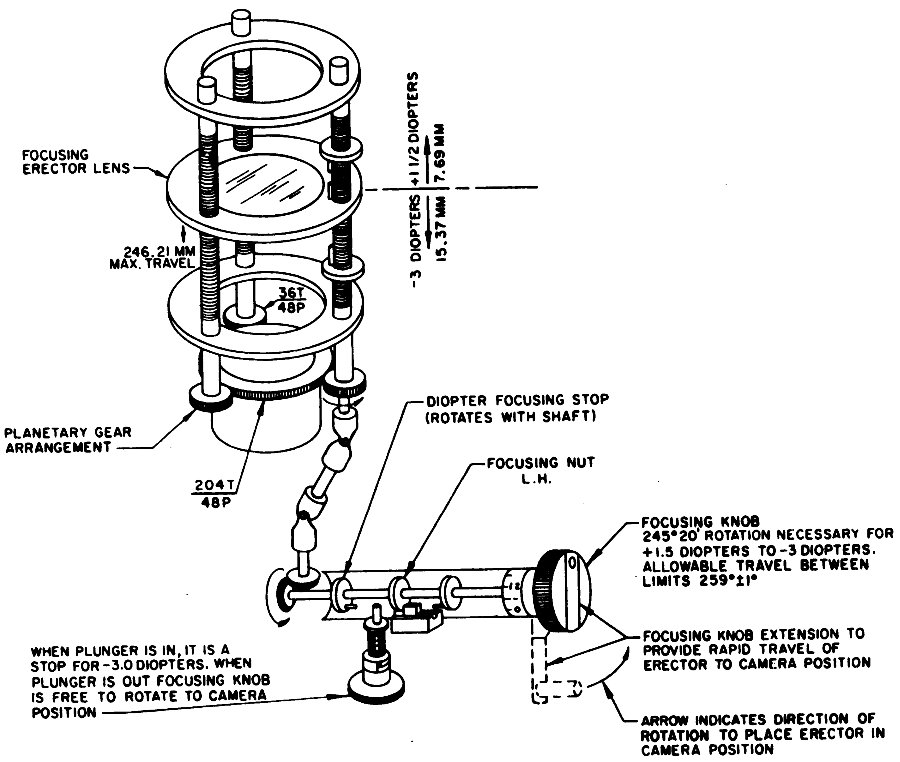

FOCUSING ERECTOR LENS
246.21 MM MAX. TRAVEL
36T 48P
+1 1/2 DIOPTERS 7.69 MM
-3 DIOPTERS 15.37 MM
PLANETARY GEAR ARRANGEMENT
204T 48P
DIOPTER FOCUSING STOP (ROTATES WITH SHAFT)
FOCUSING NUT L.H.
FOCUSING KNOB 245°20' ROTATION NECESSARY FOR +1.5 DIOPTERS TO -3 DIOPTERS. ALLOWABLE TRAVEL BETWEEN LIMITS 259°±1°
WHEN PLUNGER IS IN, IT IS A STOP FOR -3.0 DIOPTERS. WHEN PLUNGER IS OUT FOCUSING KNOB IS FREE TO ROTATE TO CAMERA POSITION
FOCUSING KNOB EXTENSION TO PROVIDE RAPID TRAVEL OF ERECTOR TO CAMERA POSITION
ARROW INDICATES DIRECTION OF ROTATION TO PLACE ERECTOR IN CAMERA POSITION

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Figure 6-7.—Focusing system.

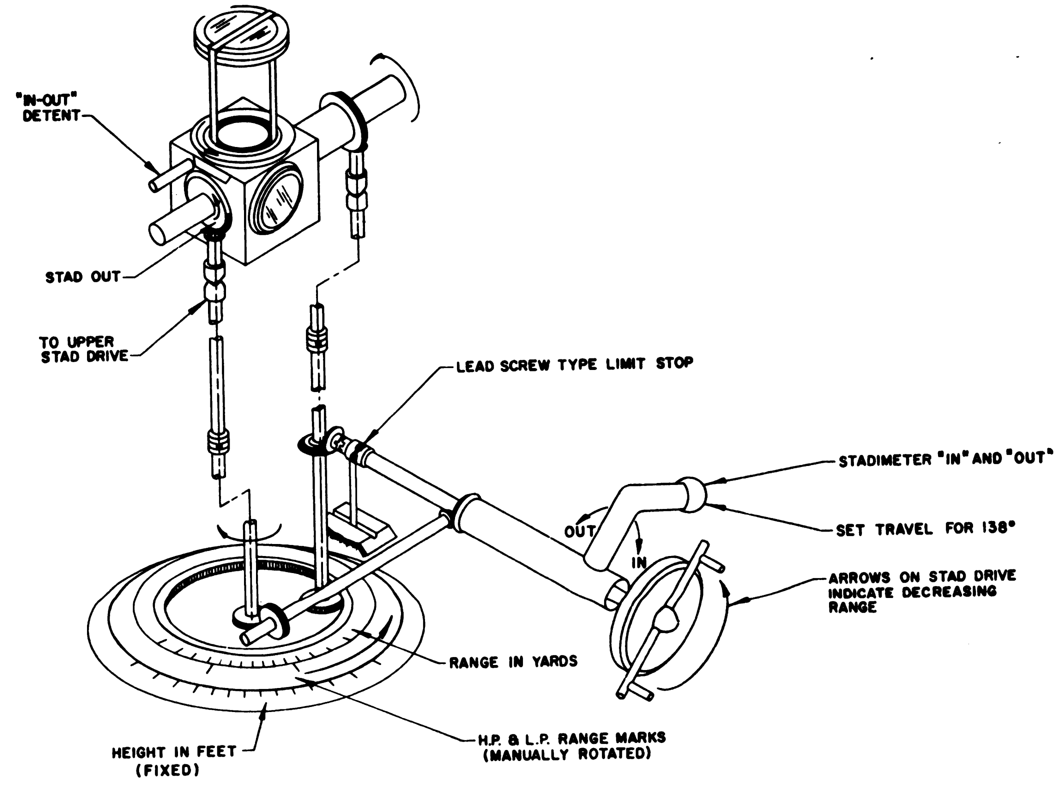
"IN-OUT" DETENT
STAD OUT
TO UPPER STAD DRIVE
LEAD SCREW TYPE LIMIT STOP
STADIMETER "IN" AND "OUT"
SET TRAVEL FOR 138°
OUT
IN
ARROWS ON STAD DRIVE INDICATE DECREASING RANGE
RANGE IN YARDS
H.P. & L.P. RANGE MARKS (MANUALLY ROTATED)
HEIGHT IN FEET (FIXED)

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Figure 6-8.—Ranging system.

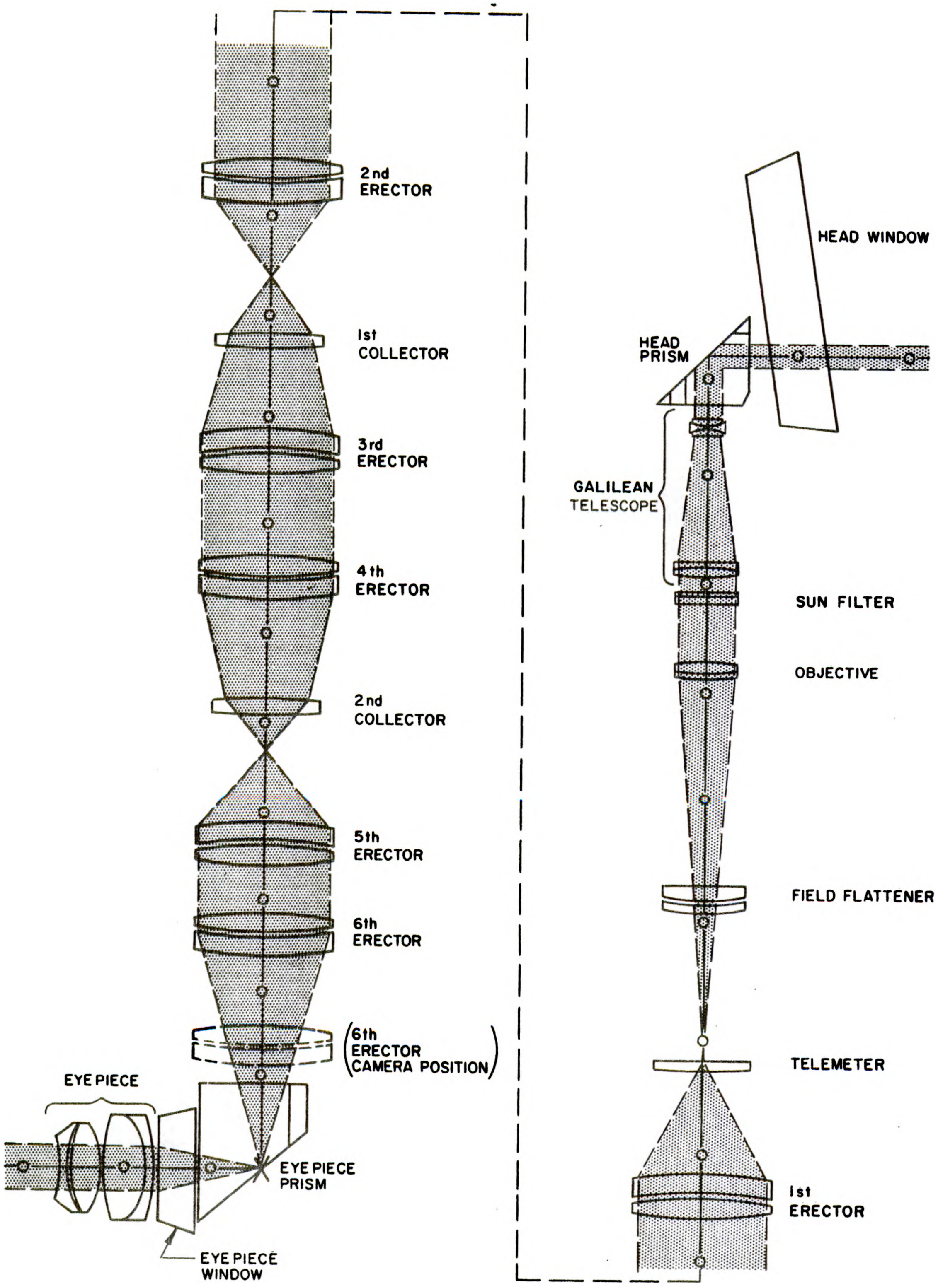

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Figure 6-9.—General arrangement of optics.

elements (fig. 6-9). The change of power system (Galilean telescope) has remained essentially the same.

Although the total number of elements within the periscope has increased, the image quality and light transmission have been improved because of the optical design. The total number of elements in the line of sight of the main telescope remains the same for all the type 2, 8, and 15 generations of periscopes, regardless of their lengths, with the exception of specific modifications, that is, the type 15 Mod 2A and the type 18 periscopes.

Component Functions

The optical elements of the type 2, 8, and 15 generation periscopes have the same function even though the elements for a particular type may vary in size and focal length. Refer to figure 6-9 as each element is discussed.

HEATED HEAD WINDOW.—Designed to withstand the seawater pressures to which the periscope is subjected, the window distributes heat uniformly to clear external fogging and prevent ice formation.

HEAD PRISM.—A right-angle prism, with its hypotenuse surface silvered, directs the line of sight downward through the periscope.

GALILEAN TELESCOPE.—A four-power telescope placed in the system in reverse to reduce the power of the periscope when the telescope is rotated into the line of sight. Rotating the Galilean telescope into the line of sight enlarges the field of view and makes possible a rapid search of the horizon when the submarine is at periscope depth.

SUN FILTER.—A plano-parallel plate, the sun filter is used in the general-purpose periscopes to make observations of the sun for subsurface navigation and to reduce glare.

HIGH-POWER OBJECTIVE LENS.—Functions as an objective lens normally does.

FIELD FLATTENER.—Serves as a correcting lens to reduce spherical aberrations of the objective lens at the first image plane.

TELEMETER.—The telemeter lens is made of one flint plano convex element. This surface is etched with vertical and horizontal calibrations in degrees of true field and provides a means of measuring the angular size of a target. The periscope telemeter (reticle lens) performs three functions in the optical system. First, it provides a crossline in the line of sight at the first image plane to give a reference in azimuth and bearing. As the periscope is rotated, the vertical crossline is the reference for determining the relative bearing of an object. As the line of sight is elevated, the horizontal crossline (in general-purpose types only) is used to measure the elevation angle (azimuth) of an object of celestial body.

Second, the telemeter functions as a ranging device, that is, a device to measure the distance from an object to an observer. Each large division of the telemeter corresponds to an angle of 1° in high power and 4° in low power. Each subdivision corresponds to an angle of 15 minutes in high power and 1° in low power. If the height of a target is known, you can determine its range using the telemeter graduations to determine the angle it subtends. If the target is at a right angle to the line of sight, its length can be used to determine its range.

Third, the rear surface of the telemeter is convex and enables the telemeter to function as a collective lens.

ERECTORS.—Serving to transmit the image through the main body of the periscope, the six erectors of each particular type are identical in construction.

The fifth erector of attack periscopes is mounted in a rotatable cube (fig. 6-10) that

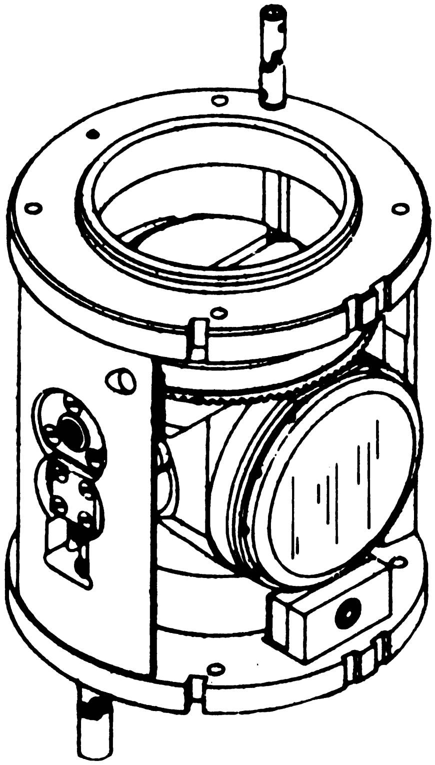

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Figure 6-10.—Stadimeter lens mechanism.

contains the fifth erector (identical to the other five erectors) and its alternate position, a split erector (of equal focal length as the fifth erector) that serves as the primary ranging device of the attack periscope.

The split erector (stadimeter lens) measures the angular height of a target by forming a double image with the masthead of one image coincident with the waterline of the other image (fig. 6-11).

The double image is formed by offsetting each half of the split lens from the other (fig. 6-12). A telescope will form a complete image of an object even though one half of its free aperture is obscured. In effect, then, there are two telescopes having a common eyepiece and one half of an objective lens in each. As each half of the split lens is moved laterally, its image is displaced a corresponding amount. When the image displacement is converted into height of the target, the range of the target can be determined. The periscope stadimeter converts target height versus image displacement into range by means of a cam and gears.

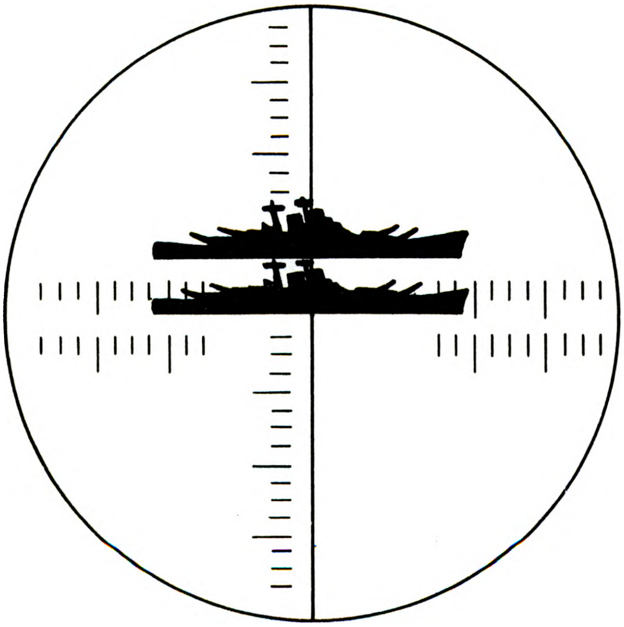

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Figure 6-11.—Ranging with the stadimeter.

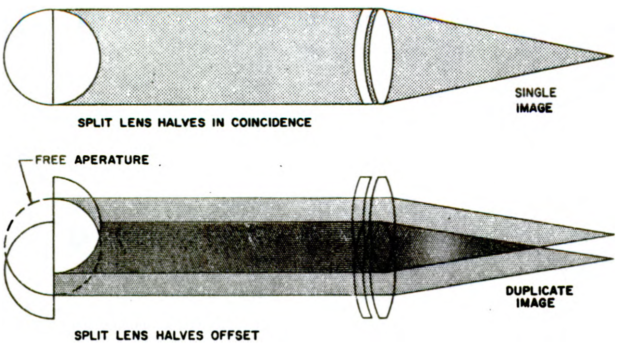

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Figure 6-12.—Operation of the split lens.

The sixth erector is the focusing erector. Its characteristics were discussed early in this chapter.

COLLECTORS.—Mounted between the second and third erectors and the fourth and fifth erectors, the two collectors are designed to improve image quality.

EYEPIECE PRISM.—A right-angled prism used to deflect line of sight 90° into the eyepiece.

EYEPIECE.—A two-doublet, externally mounted, removable assembly that has an integral electrical heater for defogging purposes. The eyepiece can be removed and replaced with a camera to put the periscope in a photographic mode.

MAINTENANCE SYSTEM

The maintenance of submarine periscopes is similar to that of other optical instruments in that the same procedural steps are followed—premaintenance inspection, cleanliness, disassembly and repair, reassembly and collimation, and charging.

Premaintenance Inspections

In general, inspect any periscope before its removal and overhaul. The inspection of a periscope should include checking the condition of the optical, mechanical, and electrical system, and the external condition of items subject to wear.

Maintenance inspection sheets should be used to record the preoverhaul and postoverhaul conditions of each periscope. Use the appropriate technical manual for reference when you are making a maintenance inspection sheet.

Cleanliness of Various Optical Elements

Because the large number of elements in the line of sight of a submarine periscope, cleanliness of all the optical surfaces is extremely important. In the long run, it is easier to keep the elements clean (by protecting them against contamination) than to clean them once they get dirty. Whenever any of the inner tube sections are separated, immediately cover the ends to prevent entrance of foreign matter.

Keep in mind that a periscope is overhauled in a horizontal position, but used in a vertical position. Foreign matter inside the inner tube may fall onto the lenses as the periscope is placed upright, causing loss of time and effort caused by rework. If it is practical, the periscope should be tested for cleanliness in a vertical position before installation.

You may check the cleanliness of some internal elements, while the inner tube is assembled, by focusing on them with the focusing knob. As the focus is varied, the surfaces of individual elements will appear in focus to the repairman.

TELEMETER.—Keep in mind that the telemeter is in focus whenever the periscope is being used. Any foreign matter on the telemeter will bother the user.

FIELD FLATTENER AND COLLECTOR LENSES.—Foreign matter on the field flattener or collector lenses may be detected by focusing the periscope from one extreme of the focusing range to the other extreme. The field flattener will come into focus near the negative extreme of the focus range while the collector lenses will come into focus close to the normal viewing focus range.

EYEPIECE PRISM.—The upper surface of the eyepiece prism lies near an image plane, and, therefore, any dirt on it will appear in the field of view.

ELEMENTS EXTERNALLY VISIBLE.—You should check the cleanliness of various elements without looking through the periscope. Foreign matter can be readily detected on the windows, prisms, Galilean telescope elements, and the eyepiece by visual inspection where it might not be apparent to you when looking through the periscope.

Disassembly and Repair

Periscopes seldom wear out; they are just too well made. Entry of moisture, careless maintenance, oil vapor on optics, failure of electrical/electronic components, unauthorized tampering, and misuse in service are the predominant causes of failure. Periscopes have been used for ice picks and can openers with disastrous results. If subjected to excessive speeds while raised, a good portion of inner tube disassembly may take place automatically. Discounting all problems caused by "the other guy," periscopes require an annual overhaul as a preventive measure.

It is hard to imagine the degree of precision in periscope construction unless you have actually worked on these instruments. For instance, when the left-training handle is rotated slightly, the rotation is transmitted through four spur gears, two sets of bevel gears, numerous universal joints, 35 to 40 feet of shafting, a self-centering coupling to a worm and sector attached to the head prism mount. When the handle is turned, the head prism moves; lost motion or backlash is practically nonexistent.

You must use the same degree of care and skill in your work on periscopes as the manufacturer used in designing and making the instruments. The way you will obtain this skill is through experience in assisting with periscope repair jobs.

Periscope repair is seldom done by one individual. You may need to use three hands or be in two places at once. Usually, a team of three or four people is needed to strip an inner tube. Although no starting point is specified, the following steps must be performed before inner tube sections can be separated.

Before you withdraw the inner tube, internal gas pressure of the periscope must be released.

Make certain the head prism is set at 0° elevation, and the periscope is in the low-power position.

Remove the two setscrews that secure the lower coupling to the outer tube and eyepiece box.

Using a spanner wrench, turn the lower coupling counterclockwise (as viewed from the bottom of the eyepiece box) and restrain rotation of the eyepiece box and outer tube.

NOTE: The coupling has right-hand threads at the upper end and left-hand threads at the lower end so that backing off on the coupling draws the inner structure out of the outer tube.

CAUTION

When you remove the inner skeleton, be sure that the eyepiece box is fully supported at all times. At no time must the overhanging weight of the eyepiece be supported by the aluminum inner skeleton of the periscope.

Once the coupling is loose, the inner structure may be withdrawn. Slowly withdraw the inner structure. As the inner tube is withdrawn, cover all inner tube openings to prevent any additional contamination.

On the general-purpose type periscopes, remove the retainers which secure the radar waveguide and various antenna cables or conduits to the inner tube flanges. These components are usually lifted off as a unit and set in racks under the periscope rail.

NOTE: Use portable, compartmented parts trays to hold the various nuts, bolts, washers, and retainers.

Next, remove the electrical wiring from terminal blocks on appropriate inner tube sections and place the wiring harness in racks on the periscope rail.

Finally, remove shafting for the focusing erector and head prism. On type 2 periscopes, remove split lens in-out shaft and range shaft.

CAUTION

Shafts are separated at universal joints. The shaft and joint sections are held together with taper pins or, in some cases, a key and keyway. You must firmly support the U-joint while tapping out the taper pin. Tape the pin to the U-joint if it is to be reused.

Release tension on the power shift tapes. Remove the tapes from the power shift racks above the eye box and at the head section. At this point, you can pull the tapes from the inner tube guides and roll them carefully in a 6- or 7-inch roll.

Next, you can separate the various inner tube sections to gain access to the optics and focusing erector, skeleton head, and, in the type 2, the split lens mechanism.

Inner tubes are held together with five self-locking socket head cap screws per section. Support assembled sections in V-blocks, as you remove the shorter sections, to avoid dropping any portion of the inner tube structure. Any sudden drop, even through it may only be 3 inches, is often enough to chip a $200 lens. As you pull each inner tube section apart, cover the open ends with masking tape to keep out lint or dust.

Inner tube sections are numbered to show their location in the periscope. Some of them are so similar that improper reassembly is possible. The shop that performs the first overhaul on a scope numbers the inner tube sections before disassembly.

- Carefully remove and mark the various lenses. The high-power objective and erectors are mounted in adjustable cells. The telemeter, field flattener, and collectors are retained in their respective tube sections.

NOTE: The sixth erector (focusing erector) is a separate unit. The fifth erector in type 2 periscopes is the split lens mechanism.

- Disassemble the eye box component assembly. A type 15 eye box is shown in figure 6-13. Components of the type 2 eye box are somewhat different since attack periscopes do not have a synchro mechanism or antenna waveguide and cables. The type 2 eye box also has provision for two additional control shafts. (Split lens drive and stadimeter in-out drive.)

Be extremely careful when you remove the following stuffing box assemblies (right-training handle, left-training handle, focusing knob, and telemeter rheostat) since they can be withdrawn only from the inside of the eye box. Do not damage any O-ring seats.

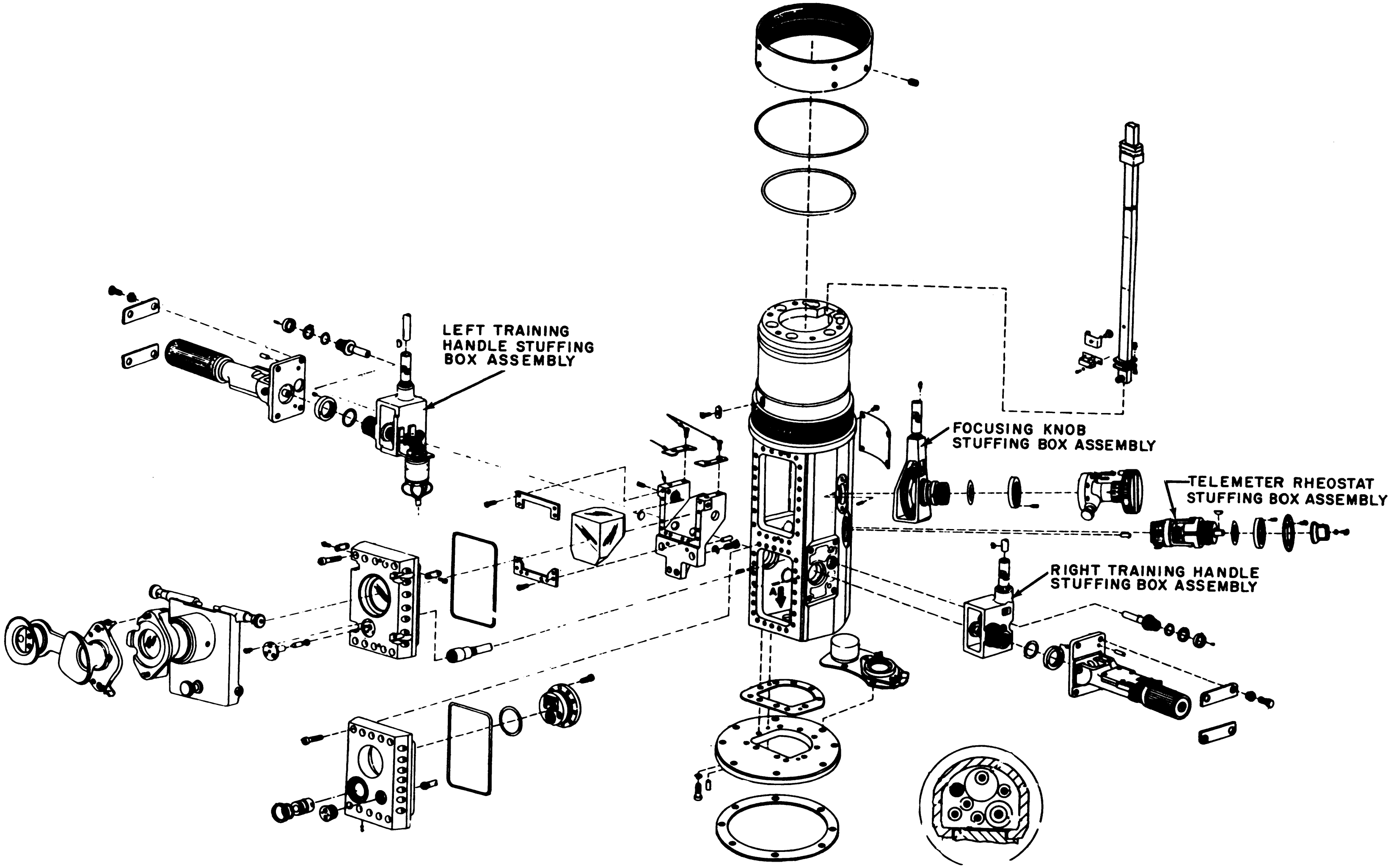
LEFT TRAINING HANDLE STUFFING BOX ASSEMBLY
FOCUSING KNOB STUFFING BOX ASSEMBLY
TELEMETER RHEOSTAT STUFFING BOX ASSEMBLY
RIGHT TRAINING HANDLE STUFFING BOX ASSEMBLY

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Figure 6-13.—Eye box and component assembly.

- Disassemble the focusing erector assembly. The exploded view (fig. 6-14) is common to all periscopes. If there is no damage to the focusing erector assembly or if lubrication or adjustment is not necessary, you can remove the lenses for cleaning without taking the entire mechanism apart.

- Remove the access screw from the housing and raise the lens mount by turning the universal joint until the setscrew is visible through the housing. After loosening the setscrew, remove the lenses in the usual manner.

If complete disassembly is required for any reason, remove the upper and lower bearing plates, retainers, and clamps. Slide the rest of the assembly out the bottom of the housing. Mark all components you remove if they are not damaged. You can replace them in their original positions.

Notice the extensive use of dowel pins in the focusing erector mechanism. The dowels maintain

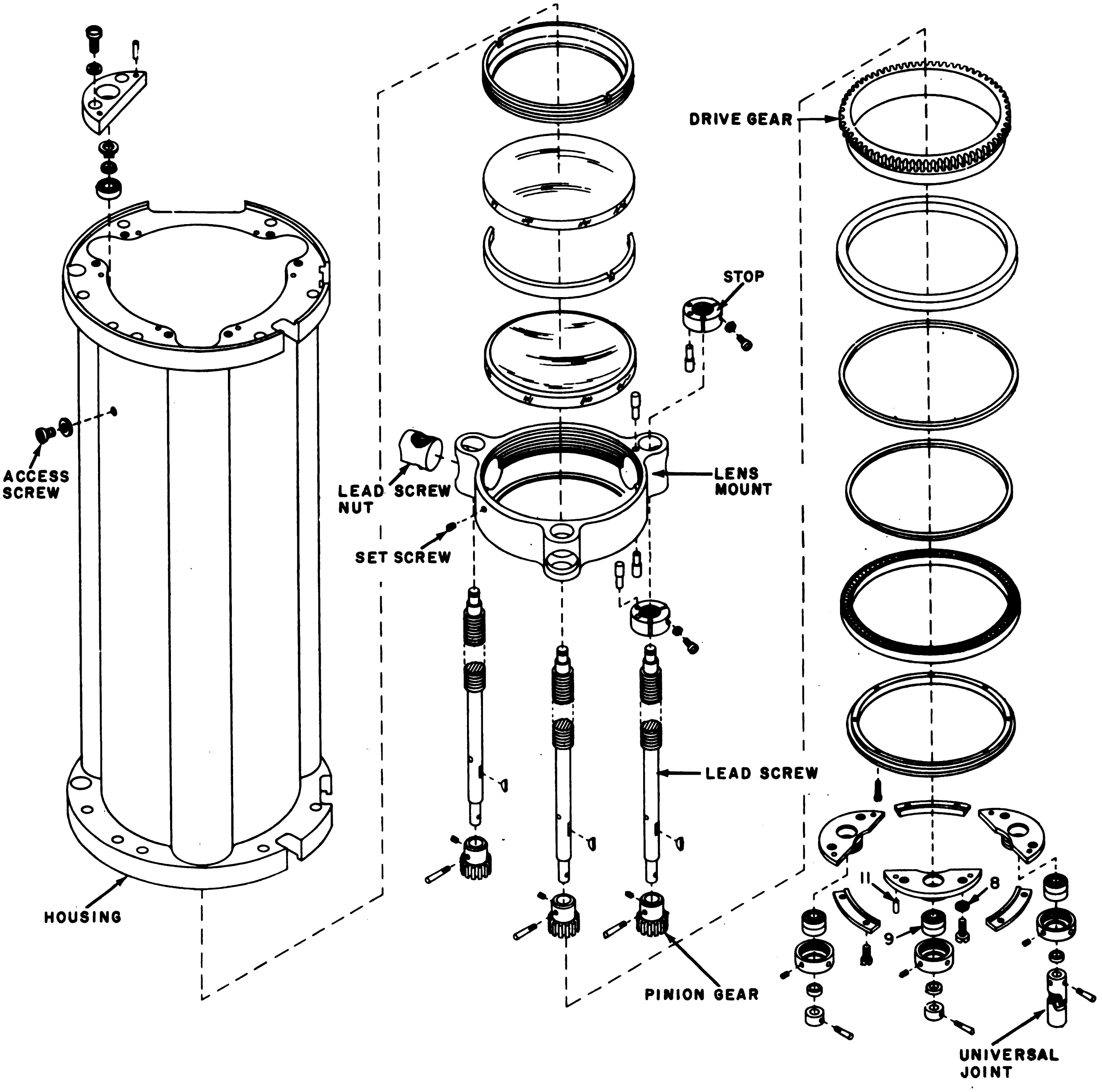

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Figure 6-14.—Focusing erector assembly.

alignment of the three lead screws throughout the full travel of the lens mount, which is over 10 inches. If the lead screws were not perfectly parallel with each other, the lens mount would bind, and, if the lead screws were not parallel with the outer housing, the line of sight would not correspond with the mechanical axis of the periscope.

Other alignment problems occur because the multiple lead threads are machined on the lead screws. When the lead screws are inserted into the lead screw nuts, you must catch the correct lead so the pinion gears will mesh properly with the drive gear. Also, bear in mind that the shoulders on the pinion gears should be equidistant from the face of the drive gear when the unit is assembled.

Clamp the stops to one lead screw to limit travel of the lens mount and to prevent the lens mount from being turned off the ends of the lead screws. Set the lower stop about two threads from the end face of the lead screw threads, and clamp the upper stop about 1 inch from the upper end of the lead screw. Final positioning of the upper stop is done during final assembly and collimation.

If you replace any parts in the focusing erector assembly, test the entire unit for binding or excessive play by assembling the unit, using setscrews to secure components. Once you verify the proper operation, drill and install dowel or taper pins.

- Disassemble the skeleton head assembly. The skeleton head shown in figure 6-15 is a type 2 scope. The skeleton heads used on general-purpose periscopes are similar in function but different in detail, and about three times larger.

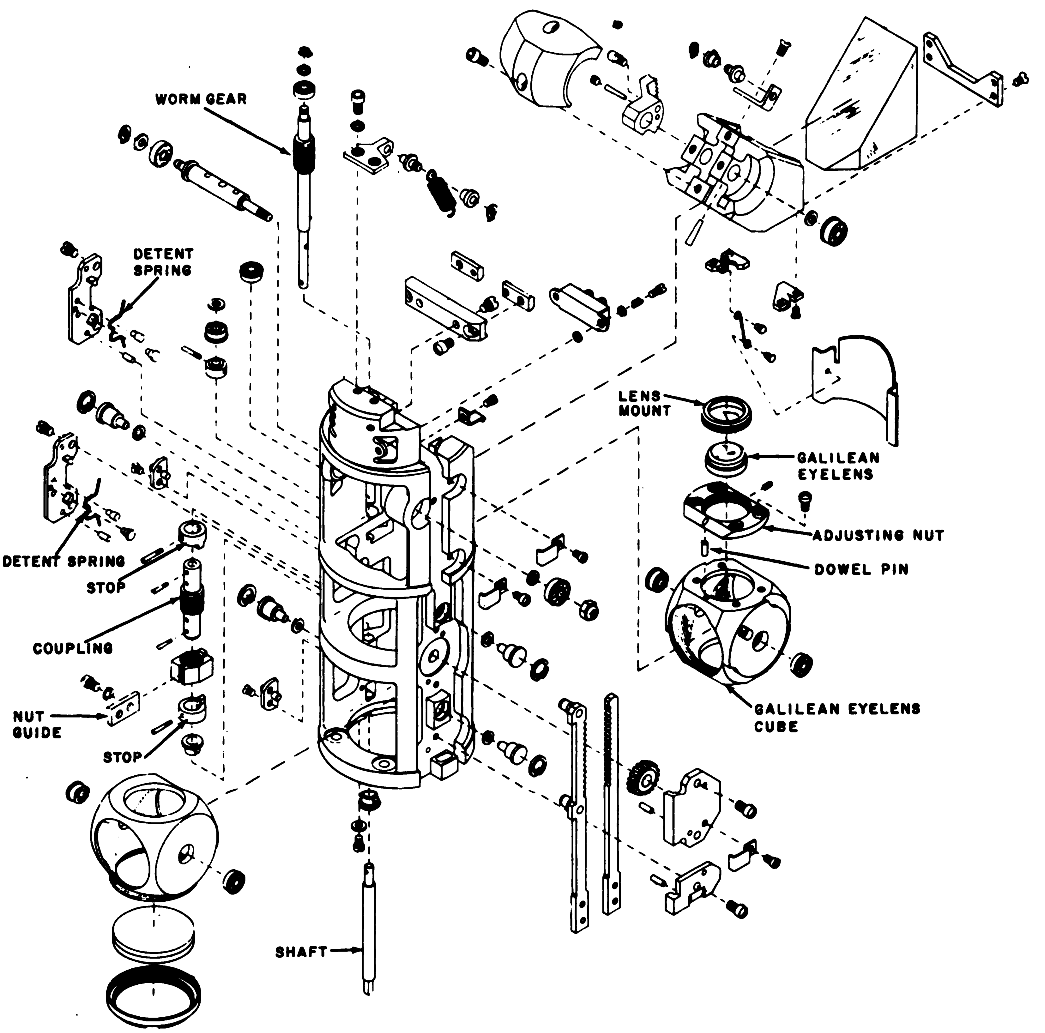

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Figure 6-15.—Head skeleton and component.

As you can see in this figure, a periscope skeleton head is somewhat more complicated than the average snap-together model kit. Completely disassemble one of these units when seawater enters and contaminates the assembly or when a head prism breaks, spreading fine glass particles through the mechanism. Any Opticalman can replace head prisms and Galilean eye lenses or objectives, but only a highly skilled repairman can accomplish a complete disassembly.

All rotating or pivoting elements of the skeleton head are supported by ball bearings, which provide friction-free movement. These bearings are slightly preloaded with precision-machined spacers to eliminate any end play. Cleanliness and proper lubrication of bearings and bearing surfaces are essential to maintain the precision of the skeleton head.

Since the Galilean telescope shifts in and out of the line of sight, the Galilean eye lens cube has several adjustments to align the low-power line of sight with the high-power system. The Galilean eye lens is held in a lens mount, which screws in and out of an adjusting nut to provide parallax adjustment. The screw holes in the adjusting nut are elongated so the adjusting nut can be pivoted left and right around a dowel pin to eliminate displacement of the line of sight when the periscope is shifted from high power to low power. Detent springs hold the two cubes in either the high-power or low-power positions.

The basic elevation mechanism components in the skeleton head consist of a shaft coupling and worm and worm gear assembly. Associated bearings, spacers, pins, and retainers can readily be seen in figure 6-15. Note that the worm and worm gear make up a matched set and must be replaced, if necessary, with another set. The elevation stops in the skeleton head consist of a nut, stops, and coupling. The stops are pinned to a coupling which is free to rotate. Rotation of the coupling drives a nut up or down until it contacts the upper or lower stop. A nut guide engages a slot in the nut to prevent it from rotating. The elevation stops in the type 2 skeleton head are set to provide 1/4° of elevation overtravel at +74° and −10°. The stops in the left-training handle should engage before the stops in the skeleton head to prevent damage to this delicate mechanism.

After reassembling the skeleton heads of general-purpose periscopes, you must make several important tests. Since these scopes are used for celestial navigation, the zero elevation position of the head prism must be established, the head synchro must be aligned electrically to read zero elevation, and a backlash test must be run on the elevation mechanism.

These tests and adjustments are necessary so that the navigator of the submarine will know how much error to expect for any angle of elevation. You will find tables and procedures for conducting the elevation tests and adjustments in the appropriate periscope technical manuals and in NAVSHIPS 0924 001 0000 (Altiscope Angle Comparator).

- Disassemble the stadimeter lens mechanism assembly. Remember, the stadimeter assembly (fig. 6-16) is found only on type 2 periscopes. The precision of machining and fit that was necessary in the skeleton head also applies to this mechanism. Mark all the parts you remove as an aid to reassembly.

Several problems of mechanical and optical alignment are unique to this assembly. First of all, bevel gears are used to operate the split lens and to shift from split lens to solid erector. Meshing of these gears must be perfect to eliminate backlash. Secondly, when the cube is shifted from solid to split lens and vice versa, displacement of the line of sight must not exceed ±5 minutes of arc. Thirdly, the split lens and solid erector must be parfocalized (focal lengths of the lenses must be equal) within ±0.5 mm of focal length. Since the split lens is more expensive and more complex, adjustment is made by machining spacers in the solid erector or by replacing both solid erector elements. Finally, when the cam gear is turned to operate the split lens, a rotation of a set number of degrees must result in a rigidly specified movement of the two split lenses. The tolerance allowed for this movement must be within ±0.0003 inch.

There is nothing simple about any work performed on the stadimeter lens mechanism assembly. You will need a high degree of skill and patience to disassemble, repair, reassemble, and adjust this unit. You must strictly adhere to the step-by-step procedure outlined in NAVSHIPS 324-0487.

Cleaning

Some cleaning of optics and mechanical components, such as skeleton head, 6th erector eyepiece box, and split lens, is done during the repair and reassembly phase of overhauling individual periscope assemblies. All possible forms of contamination must be eliminated in preparing a periscope for reassembly. Lubrication must

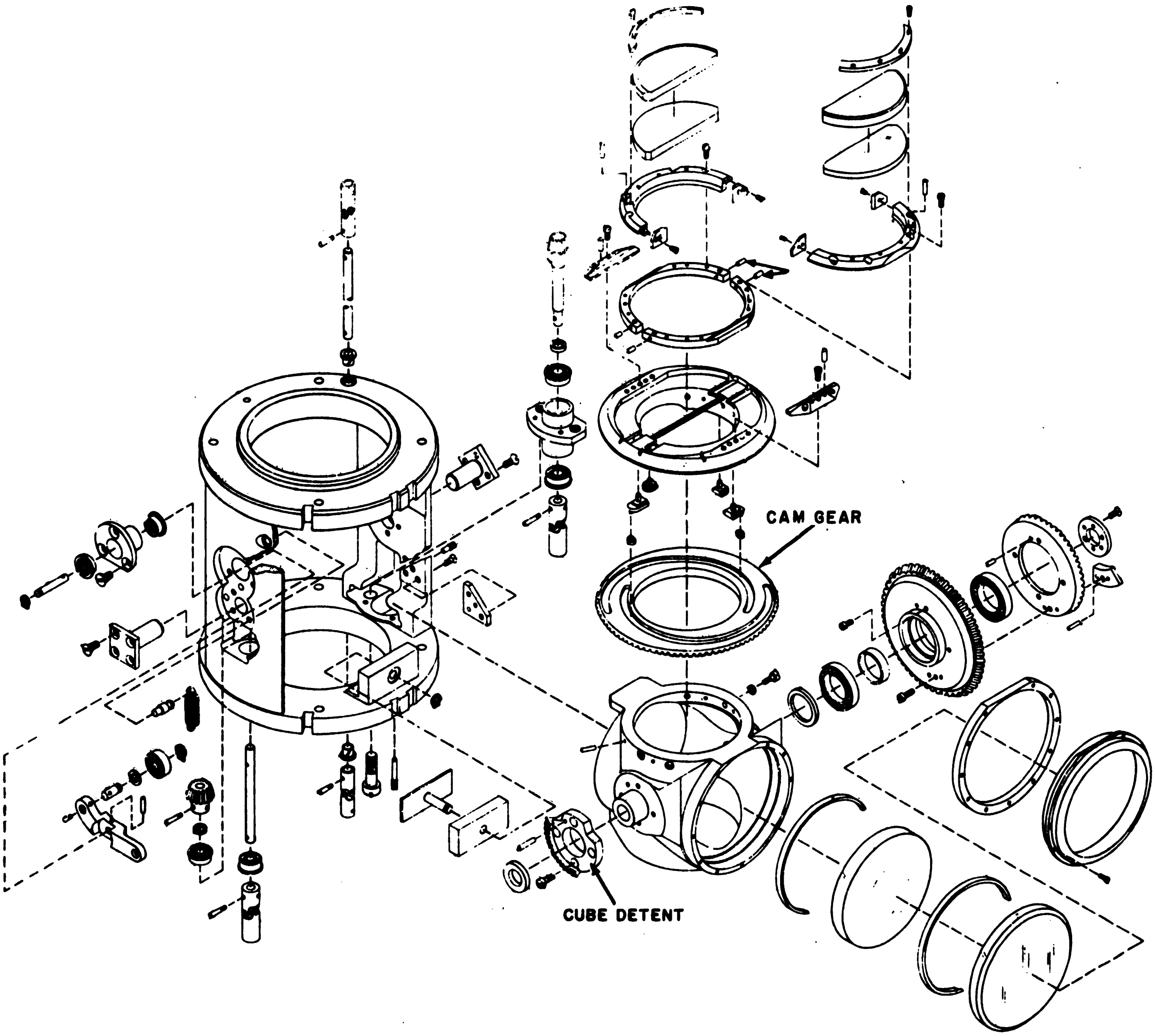

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Figure 6-16.—Stadimeter lens mechanism and component assembly.

must be applied sparingly; mechanical assemblies should slide together smoothly to avoid formation of metal shavings. Inner tube sections must be thoroughly cleaned to remove particles which could fall on optics.

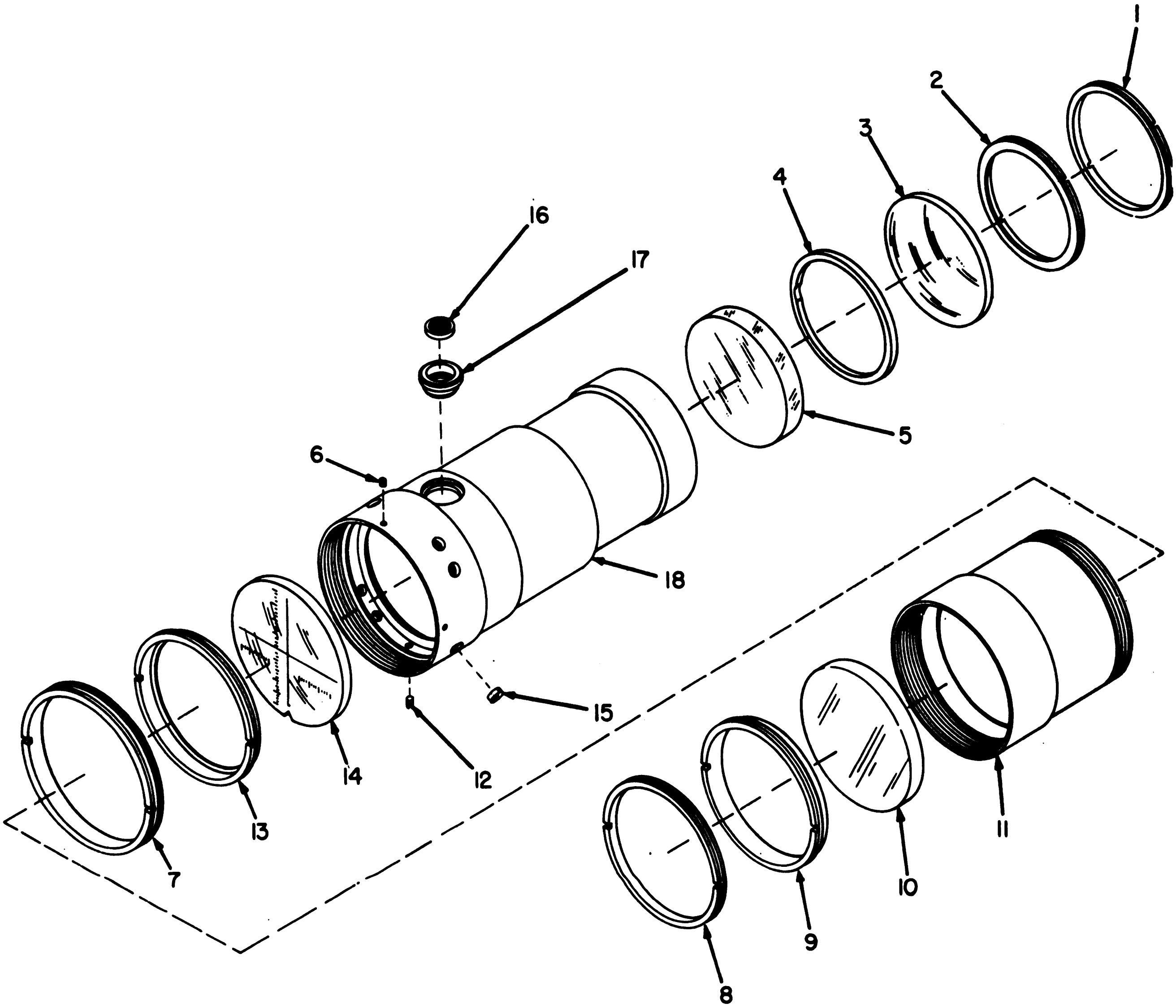
During disassembly, when lens mounts were removed, the open ends of inner tube sections were covered with masking tape. Suspend them from wire on a nylon line in the same position they would be in an assembled scope to clean the insides of these sections. Inner tubes may be rinsed clean with liquid freon (Trichlorotrilfouroethan). This removes dirt particles and oil residue from the inner and outer surfaces of the tubes.

Retape the tube sections until you are ready to install the lens mounts.

The procedure for cleaning lenses was covered in chapter 7 of NAVEDTRA 10205-C, *Opticalman 3 & 2*. Cleaning periscope optics presents several other problems.

- The erectors are quite large and acetone will leave streaks if you are not careful.

- The optics are stacked up, and any dirt in the tube sections will fall on the lenses and be visible.



1. LOCK RING, FIELD LENS
2. RETAINER, FIELD LENS
3. FLATTENER, FIELD
4. SPACER, FIELD LENS
5. FLATTENER, FIELD
6. SETSCREW
7. RETAINER, TELEMETER LENS MOUNT
8. LOCKRING, TELEMETER LENS
9. RETAINER, SEALING PLATE
10. SEALING PLATE, TELEMETER
11. MOUNT, SEALING PLATE
12. SETSCREW
13. RETAINER, TELEMETER LENS
14. TELEMETER LENS
15. FILTER, RED
16. FILTER, AIR
17. MOUNT, AIR FILTER
18. MOUNT, TELEMETER LENS

137.553

Figure 6-17.—Telemeter lens mount assembly.

- Because of the travel of the focusing erector, the surface of most lenses in the scope can be seen at various times when the erector is being cranked from normal viewing position to camera position.

- The telemeter must be super spotless—no scratches, no streaks, and no lint. Absolute cleanliness is the minimum requirement. Even in a clean room, it can take anywhere from 15 minutes to a whole day to satisfactorily clean the telemeter.

The telemeter lens mount for a type 15 periscope is shown in figure 6-17. This arrangement is similar to that used on most other type scopes. Parts 3 and 5 are the two elements of the field flattener. They are located in the telemeter lens mount. A sealing window is found only on type 15 periscopes.

The telemeter lens mount must be scrupulously clean if you hope to end up with a clean telemeter when the scope is assembled.

NOTE: Part 16 is a porous bronze air filter. Nitrogen must be free to circulate around all optics in the scope. The filter allows circulation but prevents entry of dust or lint.

Reassembly and Collimation

A submarine periscope has many separate collimation requirements, including the common requirements, such as parallax, 0-diopters, squareness of the telemeter, and elevation of the line of sight. It also has a few uncommon collimation requirements, such as nitrogen compensation, relay system collimation, stadimeter collimation, and displacement. Collimation of various subassemblies is done during reassembly.

The submarine periscope collimator is designed to reproduce the various collimation distances—optically. Place the collimator target in a threaded tube so you can move the target in relation to the collimator objective. A scale engraved on the collimator body shows the various available distances. Use the distances shown below in collimating the various periscopes in the air to compensate for the introduction of nitrogen.

Periscope	Distance	(feet)
	(HP)	(LP)
2D, 2E, 2F,	3,171	49
8B, 8C, 15B, 15D	3,171	52

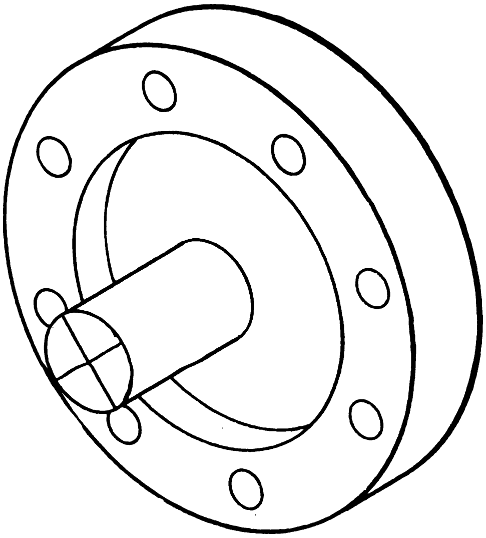
For collimating the type 18, refer to the type 18 *Collimator Manual.*

Keep in mind that these distances apply only to the assembled periscope. The procedure for collimating subassemblies will follow.

FIRST ERECTOR AND HIGH-POWER OBJECTIVE.—With the high-power objective, field flattener, telemeter, and first erector installed in the first and second inner taper tubes, place the tubes on the periscope rail in line with the periscope collimator. With an auxiliary telescope set to your eye, move the first erector until the telemeter appears sharply defined. Set the periscope collimator to the prescribed distance for high-power collimation of the particular type of periscope on which you are working. Adjust the high-power objective so that images of the collimator reticle and telemeter appear in the same plane (no parallax).

NOTE: For proper magnification of the high-power system (and optimum accuracy of the ranging mechanism), the focal lengths of the first and second erectors must not differ more than 1 percent (12 mm), and the focal length of the third and fourth erectors must not differ more than 1 percent (12 mm).

To provide the correct image plane references for collimating in air, use a special cross wire fixture similar to that shown in figure 6-18.



148.359

Figure 6-18.—Typical cross wire fixture.

Specifications for making these fixtures for different periscopes are in the appropriate periscope technical manual.

SECOND ERECTOR.—Replace the first collector lens mount with the appropriate cross wire fixture. With the second erector installed, reconnect the first and second inner tubes. Sighting through the second erector with an auxiliary telescope, move the erector to remove parallax between the collimator telescope reticle (set at infinity) and the cross wire.

THIRD ERECTOR.—Install the third erector in the lower end of the third inner tube and the appropriate cross wire fixture in the upper end of the third inner tube. Sighting through the third erector with the auxiliary telescope, move the erector to remove parallax (collimator set at infinity).

FOURTH ERECTOR.—Install the fourth erector in the lower end of the fourth inner tube. Install the appropriate cross wire fixture in the lower end of inner tube No. 5. Sight through the fourth erector and remove parallax (collimator set at infinity).

FIFTH ERECTOR.—Install the appropriate cross wire fixture into the top of the sixth inner tube. Place the tube and the stadimeter lens mechanism assembly on the periscope rail so that the fifth erector is adjacent to the lower end of the sixth inner tube. Sighting through the fifth erector, with the collimator set at infinity, remove parallax on the cross wire by shifting the entire split lens mechanism closer to or farther from the lower end of the sixth inner tube. When parallax is removed, accurately measure the distance between the flanges of inner tube No. 6 and the stadimeter lens assembly.

STADIMETER SPLIT LENS.—The fifth erector and the stadimeter split lens must be parfocalized (have their focal planes at the same point) to the point established by the cross wire fixture at the upper end of the sixth inner tube. Use the same setup as for the fifth erector except that the split lens is in the line of sight. Remove parallax again by shifting the stadimeter lens mechanism back and forth. Measure the distance between the flanges. It should correspond, within ±0.5 mm, to the distance measured for the fifth erector. If it does not, shift the fifth erector in its mount until the measurements correspond. These measurements determine the size of the spacer between the flanges of the sixth inner tube and the stadimeter lens mechanism.

NOTE: The foregoing procedure for the 5th erector/split lens applies only to type 2 periscopes. The fifth erector on general-purpose periscopes is collimated like the upper erectors.

When each of the erectors is collimated, remove the cross wire fixtures and seal the open ends of the tube sections with masking tape. Set the sections aside until ready for final assembly.

CORRECT DIOPTER SETTING.—Assemble the focusing erector assembly, lower taper tube, eyepiece box, and eyepiece on the periscope rail and focus sharply on the collimator (at infinity), using an auxiliary telescope. This is the 0-diopter setting in the air and must be adjusted for 0-diopters when the periscope is charged with nitrogen. Make the adjustment by moving the 6th erector a specified distance toward the collimator. The distance will vary with each type of periscope. Now, set the upper stop of the focusing erector assembly to allow +1.65 diopters focus travel when the periscope is charged. Adjust the stop as specified in the appropriate technical manual. Also, check the lower stop position at this time. Adjust the focus knob, if necessary, to read 0-diopters. When you are establishing 0-diopters in a non-nitrogen atmosphere with a corrected auxiliary telescope, the focusing knob should indicate −0.7 diopters.

SQUARE THE TELEMETER AND CHECK TRAVEL OF THE HEAD PRISM.—On type 2 periscopes, assemble all tube sections from the split lens mechanism through the eye box. You now have to align the split lens to the eye box. Place a leveled transit at the end of the periscope rail so you can sight the split lens. Place a machinist's square on the eye box staunching plate (90 in fig. 6-13). With the transit, sight the vertical edge of the square and rotate the eye box to align the square with the transit crossline. Now, swing the transit down and focus on the split lens. If the split lens is not perfectly aligned with the transit crossline, rotate the split lens mechanism or inner tube sections to obtain alignment.

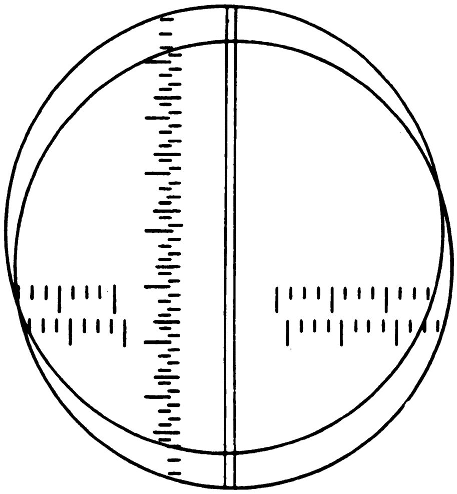
NOTE: Do not disturb the position of the eye box.

When aligning the split lens with the eye box, secure all tube sections and install dowel pins.

On all types of periscopes, after you have collimated the individual erectors, assemble the remaining inner tube sections, replace the shafting install the skeleton head, replace the power shift tapes, and install the handles.

NOTE: If new tapes are used, they must be prestressed as specified in the appropriate technical manual to prevent unwanted stretching while they are in service.

When squaring the telemeter of a type 2 periscope, operate the split lens mechanism to open the split lens. If the telemeter is not squared, you will have duplication of the vertical line of the telemeter, as seen in figure 6-19A. Loosen the screws which secure the telemeter mount and rotate the telemeter mount until duplication is eliminated (fig. 6-19B). Secure the telemeter and return the split lens to its original position.


A. DUPLICATION OF VERTICAL CROSSLINE

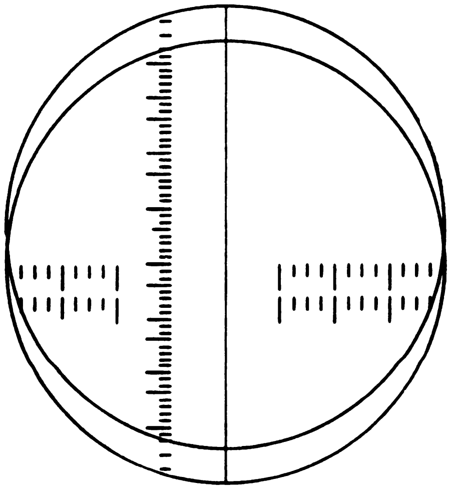

B. NO DUPLICATION

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Figure 6-19.—Duplication check.

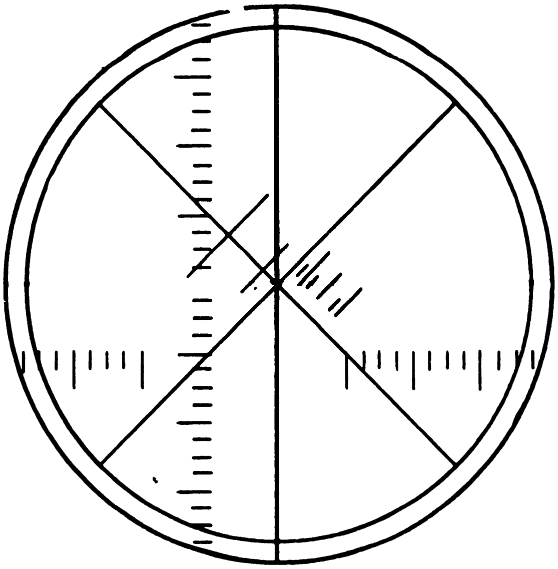
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Figure 6-20.—Collimator in rotated position (HP).

To check the travel of the head prism, set the collimator to the HP distance and align the collimator with the skeleton head. (Be sure the periscope is set in high power.) Now rotate the collimator 45° and align the intersection of the collimator crosslines with the telemeter vertical line, as shown in figure 6-20. By elevating and depressing the line of sight to the extreme edges of the collimator field, check to see that the intersection of the collimator target remains perfectly aligned with the telemeter vertical line. If the collimator target appears to track to either side of the telemeter vertical line at opposite edges of the field, the rotational axis of the head prism is not properly oriented.

NOTE: Make this check with an auxiliary telescope to magnify the telemeter and collimator images so you can more accurately determine if a possible error has been made.

If you do not have perfect tracking of the line of sight, reposition the skeleton head and/or inner tube sections above the telemeter by removing dowel pins and loosening the securing bolts between sections. After rotating the skeleton head slightly, recheck the tracking of the line of sight. Continue to reposition the skeleton head and check tracking until perfect coincidence of the collimator and telemeter is evident through the full visible travel of the line of sight.

NOTE: If you cannot obtain the necessary coincidence by rotating components above the telemeter, loosen one or more joints below the telemeter. If you must loosen the joints, you will need to square the telemeter to the split lens again before you check tracking of the line of sight.

After obtaining proper tracking of the line of sight, secure all tube sections and replace the dowel pins.

For general-purpose periscopes, set a leveled transit below the eye box in line with the axis of the periscope. Set a machinist's square on the eye box staunching plate and rotate the periscope until the edge of the square is aligned with the transit crossline. Now, shift the line of sight and focus on the edge of the head prism. If the prism edge aligns with the transit crossline, there is no problem. If perfect alignment is not apparent, proceed with repositioning the skeleton head as was done in the type 2 periscope.

After you have properly oriented the head prism to the staunching plate, square the telemeter to the travel of the head prism by observing the tracking of the collimator target on the telemeter vertical line. If perfect tracking is not evident, simply rotate the telemeter mount and recheck. When the collimator crossline remains perfectly superimposed on the telemeter vertical wire, secure the telemeter.

ELEVATION OF THE LINE OF SIGHT.— Before making the check, align (boresight) the collimator so that its line of sight coincides with the periscope's and square the collimator target to the telemeter.

The elevation/depression check may not be accurate if the collimator is not aligned because the pivot point of the head prism may not be the same as the pivot point of the collimator. Since the collimator pivot is an eccentric, it can be adjusted to the same height above the periscope collimation rail as that of the head prism pivot shaft. Once the pivot points coincide, make the elevation and depression tests.

Swing the collimator to the proper amount of elevation for your periscope (60° for 8 and 15; 74° for 2). The periscope must elevate so that the horizontal crossline touches the intersection of the collimator crosslines. Depress the collimator to −10°. The periscope must be able to depress to −10°. If the periscope will not elevate or depress as required, adjust the corresponding stop. Also adjust the left-training handle at this time so the handle graduations correspond with the line of sight.

LOW-POWER PARALLAX.—Parallax will be introduced when the Galilean telescope is shifted into the line of sight if the Galilean eyepiece lens mount is not properly adjusted. To remove parallax in the low-power system, first adjust the periscope collimator to the distance specified for the periscope. Loosen the Galilean eye lens setscrew and screw the eyepiece in or out of the mount, as required, to remove parallax. There is no tolerance for parallax; remove any that is detectable.

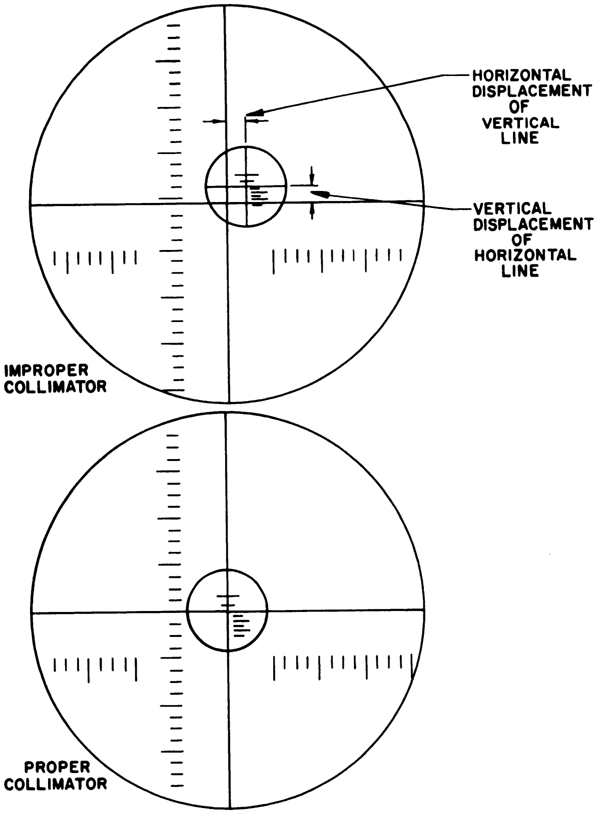
NOTE: Use an auxiliary telescope.

VERTICAL AND HORIZONTAL DISPLACEMENT OF THE CROSSLINE.—The line of sight of the Galilean telescope must coincide with the line of sight of the rest of the periscope. If not, the position of the image will change when the periscope is shifted from high to low power or vice versa. The result is an error in azimuth or bearing when you change from one power to the other.

To check for displacement, superimpose the reticle (with the periscope in high power) on the crossline of the collimator. Next shift the periscope into low power. Figure 6-21 shows correct and incorrect collimation for displacement. Horizontal or vertical displacement, or both, may appear in any quadrant of the reticle.

NOTE: The telemeter of type 2 periscopes does not have a horizontal line as do the general-purpose periscope telemeters. Compare figures 6-19 and 6-21.

To remove horizontal or vertical displacement, loosen the screws securing the Galilean eyepiece mount and shift the Galilean eyepiece laterally and/or vertically to place its line of sight in coincidence with that of the high-power system. The maximum allowable error for displacement is 2-minutes horizontal displacement of the vertical crossline and 10-minutes vertical


HORIZONTAL DISPLACEMENT OF VERTICAL LINE
VERTICAL DISPLACEMENT OF HORIZONTAL LINE
IMPROPER COLLIMATOR
PROPER COLLIMATOR

148.361

Figure 6-21.—Displacement check.

displacement of the horizontal crossline. There is no reason for you not to eliminate all displacement.

Adjust the right-training handle so the detent and index marks are properly placed. The tape tension adjustment (fig. 6-5) can be of benefit in adjusting the handle.

Stadimeter Collimation

During reassembly of the split lens mechanism, you tested the assembly for proper travel and backlash. Now, with the periscope inner tubes assembled, eliminate any movement of field evident after shifting from the solid 5th erector to the split lens, and make a range check.

Replace the stadimeter on the bottom of the eye box and test the in-out drive and the range knob. Set the collimator and periscope in high power and see if there is any displacement in shifting the split lens in or out. Remove displacement by filing or building up the cube detent (fig. 6-16).

Before making a range check, remove any duplication of horizontal or vertical lines on the telemeter. Simply cover the collimator with several sheets of lens tissue to block the collimator target, and yet have illumination.

NOTE: Move one split lens half at right angles to the split, which will adjust duplication of vertical lines. Move the other parallel to the split which will adjust duplication of horizontal lines.

There are two methods to check the ranging accuracy of the stadimeter. One is to operate the split lens to obtain coincidence of successive marks on the telemeter vertical ladder. (See fig. 6-22.) The other is to obtain coincidence of successive marks on the collimator target. (See fig. 6-23.) In the first method, set the height scale on the stadimeter dial for 100 feet. In the second method, set the height scale at 20 feet to obtain range readings.

NOTE: All range checks are made with the periscope in high power.

The second method is the preferred method for making a range check. As you can see by comparing the ranges in figures 6-22 and 6-23, the collimator ranges cover a much wider available area with a resulting increase in expected accuracy.

Accuracy of overlap ranges must be within ± 2 percent at each step in the check. If for any reason ranges do not check out correctly or if duplication cannot be removed, you may need to repeat the overhaul procedure for the split lens mechanism.

Final Assembly

When all collimation requirements have been met, secure the wiring harnesses and, in the general-purpose periscopes, the waveguide and antenna cables. Also, make a final check of all tube section joint fasteners, shafting universal joints, and screws visible on the inner tube.

Insert the inner tube in the outer tube with the eyepiece facing down and the head prism facing up with the scope in low power, zero elevation. The inner tube must be perfectly aligned with the outer tube and evenly supported to prevent sagging. As you carefully insert the inner tube in the other tube, wipe all inner tube sections and flanges with acetone and a lint-free cloth.

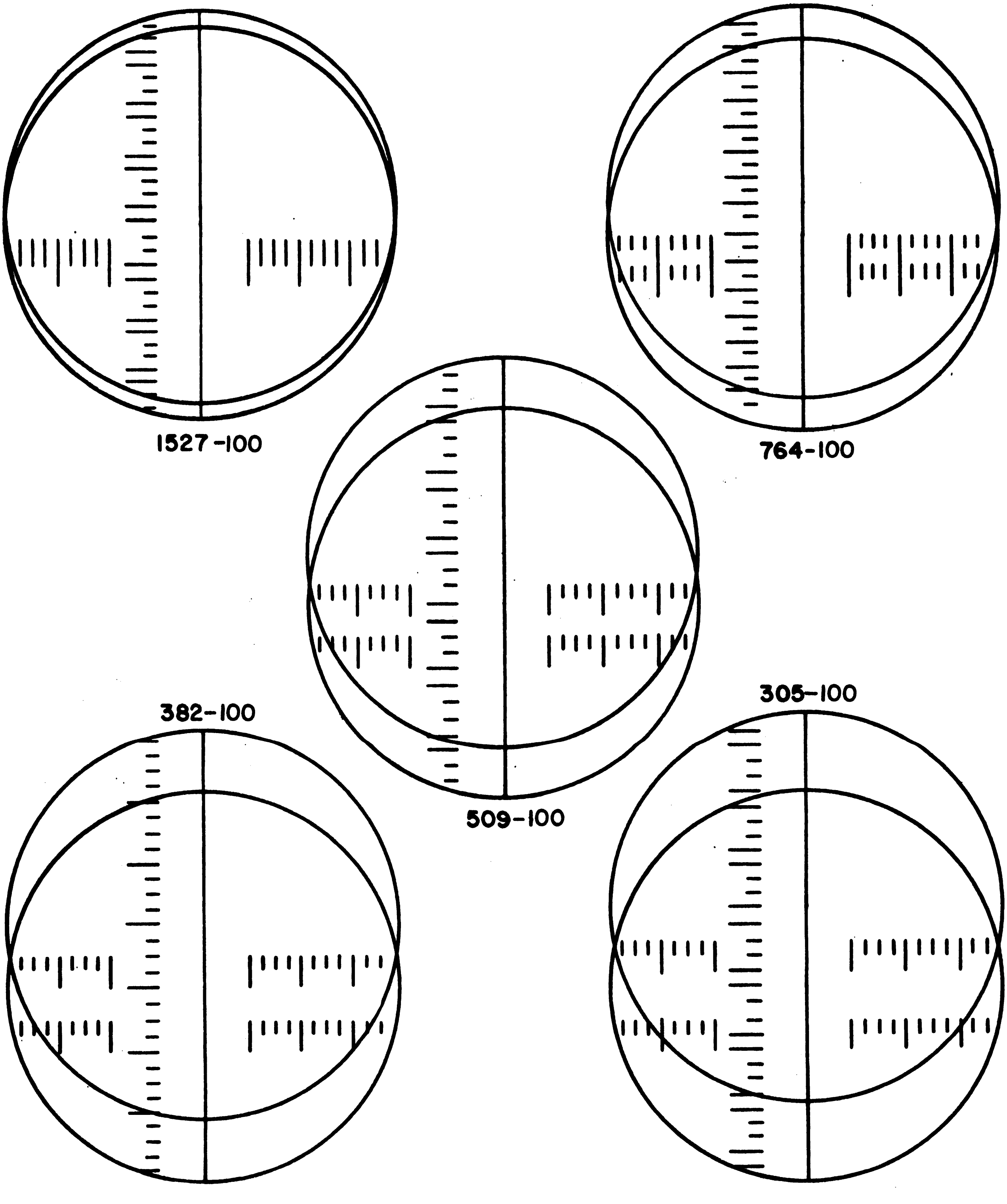


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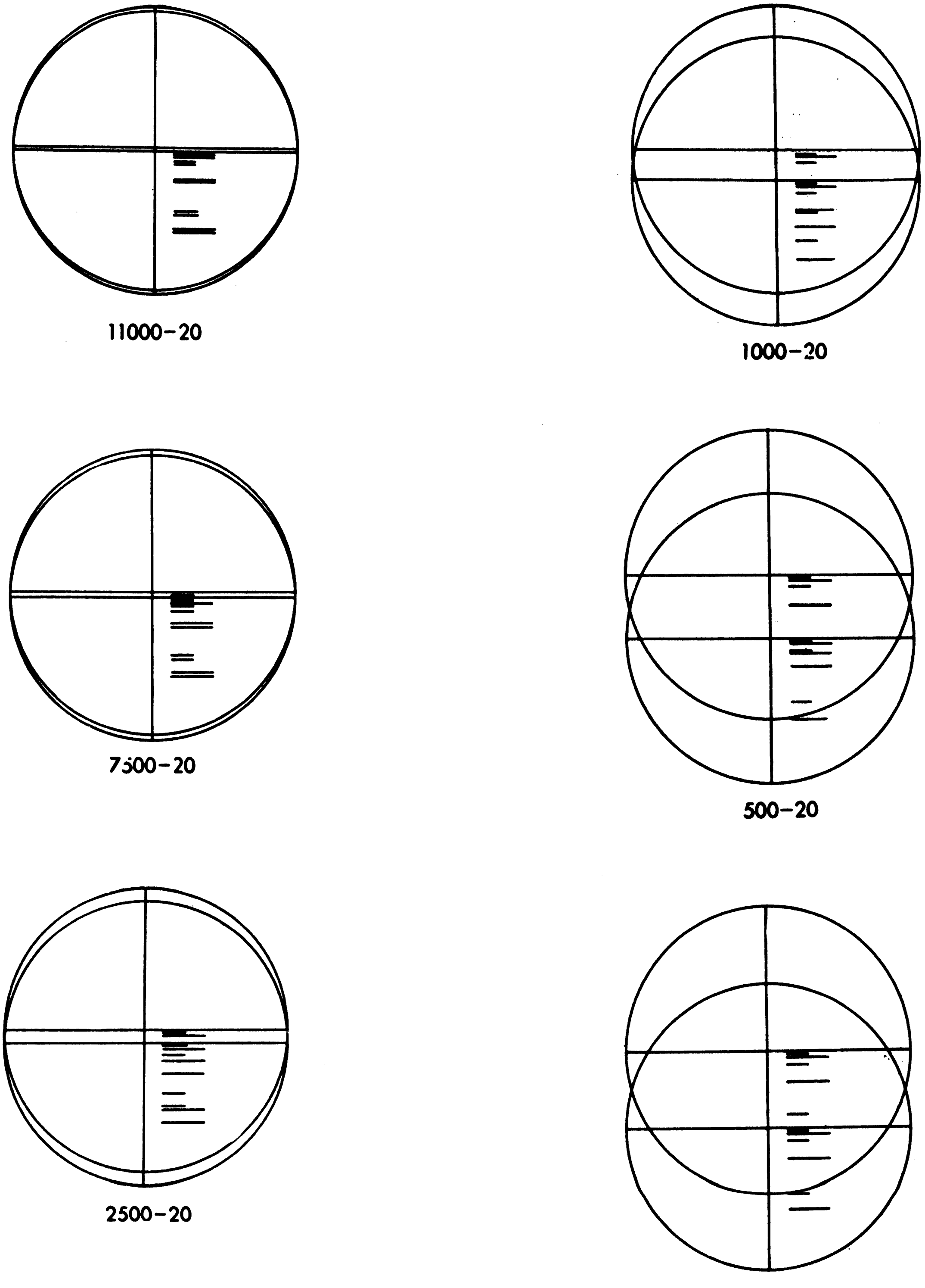
Figure 6-22.—Telemeter range references.



11000-20

7500-20

2500-20

1000-20

500-20

400-20

148.366

Figure 6-23.—Collimator range references.

Take particular care with the last foot of inner tube as it enters the outer tube. The O-rings that seal the scope are in this area; the threads of the main coupling must not be damaged; and the inner tube key must remain aligned with the outer tube keyway.

As the inner and outer tubes come together, rotate the main coupling by hand counterclockwise until you feel two jumps. This indicates the starting leads of the threads. One person is needed now to push the bottom of the eye box and maintain alignment between the inner and outer tubes, while another tightens the main coupling.

When rotating the coupling two or three times, measure the distance between the coupling and tubes—the distance should be within 1/16 inch. If the measurement is not correct, you did not catch the eye box or outer tube threads at the same time the main coupling was started. Eventually, when the coupling engagement is correct, tighten the coupling with the special spanner and slug it tight with a mallet.

The final step in periscope assembly and collimation is to establish a true optical zero elevation. In the general-purpose periscopes, the head synchro is electrically aligned with the mechanical zero of the head prism. No such check is made on the attack-type scopes. Also, because of the thickness and mounting angle of periscope head windows, some optical displacement will be present and must be compensated for.

Since general-purpose periscopes are used for navigation, setting the true optical zero position is especially important. A fine synchro (36X) on the skeleton head and a coarse synchro (2X) in the eye box are connected to the elevation shafts and gears so that they transmit continuous electrical elevation information to a remote recorder. After true optical zero is found, the electrical signal is adjusted to read zero elevation in the recorder.

To find optical zero, mount either two transits or two Mk 8 collimator telescopes (with eyepieces) at right angles to the periscope facing each other. Adjust the transits or collimators to align the crossline of one instrument with the crossline of the opposite instrument. Check back and forth between both instruments until perfect coincidence is established.

Position the periscope so you can superimpose the telemeter on the crossline of one alignment instrument.

Roll the periscope and sight the crossline of the opposite instrument. Note the amount of displacement and direction of displacement from the first sighting.

NOTE: You should be concerned only with displacement between the horizontal line of the telemeter and the vertical line of the alignment instrument crossline.

To correct displacement, remove half the error with the scope elevation handle, then align the test instrument with the telemeter. Now, adjust the opposite test instrument to the first instrument. Superimpose the telemeter on one test instrument and roll the scope again.

Continue checking one test instrument then the other, making adjustments as necessary, until perfect coincidence of the horizontal lines is established.

The electrical output signal of the synchros can now be read and recorded so the final zero elevation information can be corrected after the periscope is installed.

For attack type periscopes, once zero elevation is established, adjust the zero elevation detent in the left-training handle.

ELECTRICAL SYSTEM

All the periscopes in service now require various electrical checks from basic electrical continuity and resistance to major electronic tests. The extent of these test depends on the type of periscope. The skills you need to complete all necessary checks on the newer types of periscopes are equivalent to those of a television repairman. To gain these skills, you should complete the Navy Electricity and Electronics Training Series (NEETS) Modules as designated in the current issue of NAVEDTRA 10052.

Continuity and Resistance Checks

Continuity and resistance checks are normally done with a multimeter by connecting the test leads to various pins in the quick-connect plug on the eye box. Most of these checks are done on illumination and heating circuits.

Ground Testing

Testing of the wiring insulation, called ground testing, is done with a megohmeter (megger). But you should only test pins that are specified either in the appropriate technical manual or in shop casuality analysis sheet. The amount of voltage produced by the megger is critical. Since excessive voltage can damage some electronic equipment, these publications must be followed throughout.

ESM Circuit Testing

Electronic tests on the periscope ESM circuits assure the operational status and performance of each reception channel after the periscope is fully assembled. Tests of the overall ESM function are made from the applicable antenna to the output distribution connection. RF gain measurements are taken between the ESM intercept antenna and the amplified RF output connections of the auto coupler on the bottom of the scope. The general test method is to use RF substitution where a calibrated signal source is introduced to the system in a test setup (fig. 6-24). As shown in this figure, the test equipment includes a signal generator, a detector, and a standing wave ratio (SWR) meter. Since you will be using this type of test equipment periodically, a brief discussion of this equipment follows.

Signal generators are used for testing, aligning, and troubleshooting various electronic equipment. They produce standard sources of ac energy. A signal generator may produce audio or radio frequencies depending upon the type selected.

Many generators have output meters so that the output can be adjusted and maintained at a standard level. Also, some generators have calibrated networks of resistors called attenuators (A in fig. 6-24). These are used to regulate the output signal to avoid overloading the circuit receiving the signal. They can also provide impedance matching if the signal generator is connected directly to the circuit being tested.

When testing the ESM circuit, you should use an RF signal generator that produces the appropriate RF frequency for each reception channel. This generator should also have the capability to produce an internal modulated tone.

To determine the progress and loss/gain of the signal through the circuit, use a receiving and measuring device. Use a detector (B in fig. 6-24) to recreate the modulated frequency from radio frequency. Feed these into the SWR meter (C in fig. 6-24) which is used to measure the signal strength. The measured loss/gain values should be recorded as a reference standard to evaluate future circuit degradation.

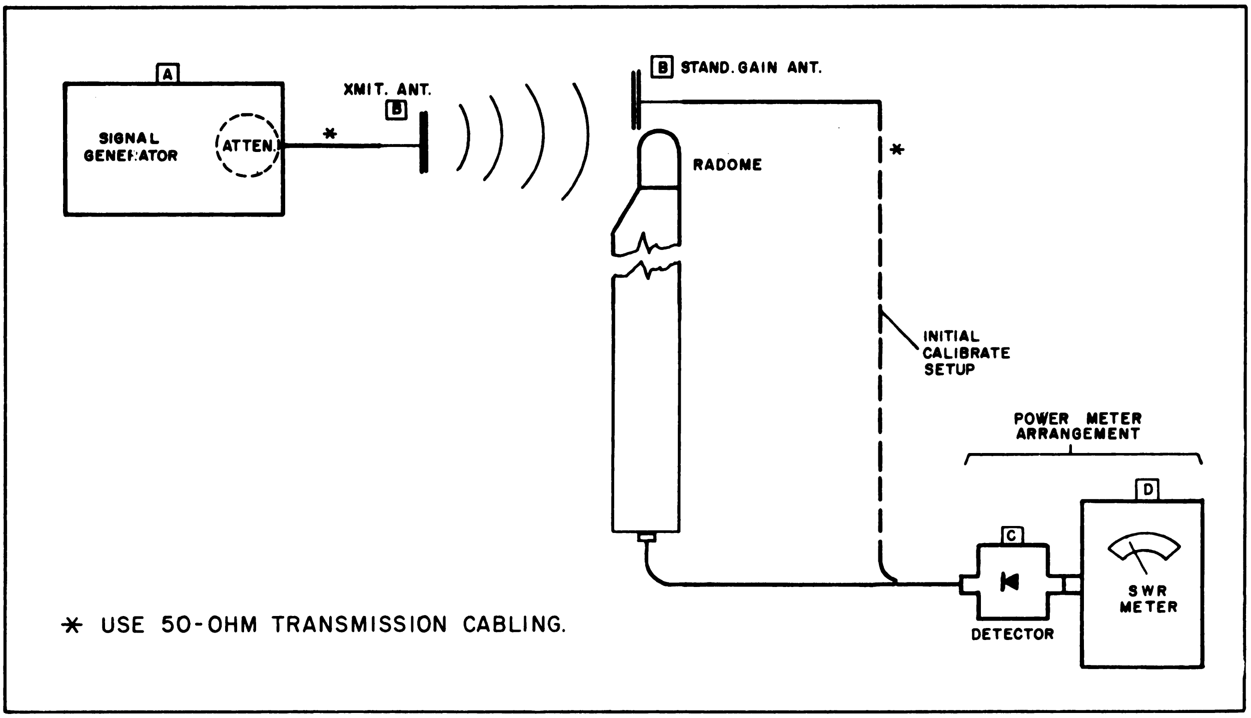


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Figure 6-24.—Test setup for communications-band and RF gain measurements of periscope ESM function.

CHAPTER 7

SUBMARINE PERISCOPES II

This chapter provides additional information to that found in NAVEDTRA 10205-C, *Opticalman 3 & 2*. It discusses in detail the safety of submarine periscope handling and communications. For those of you who are not yet on board submarine tenders, it will introduce you to SUBSAFE and level 1 materials and provide information about the latest cycling procedures. We recommend that you review chapter 12 of the OM 3 & 2 before reading this chapter.

PERISCOPE REMOVAL AND INSTALLATION

Naval Sea Systems Command in conjunction with the Naval Safety Center has conducted lengthy tests to determine what procedures and equipment should be used for mast removal and installation. Their recommendations include inspection and safety requirements for attaching slings, lifting clamps, and backup clamps to periscopes.

LIFTING CLAMP

A lifting clamp is used to attach a crane or another device to a periscope assembly for the purpose of installing or removing the assembly. A clamp should be locally manufactured (fig. 7-1) and tested at 6,000 pounds in accordance with NAVSEA D149 SS 904-4398614. It should be made of steel and have a brake lining insert. Bolt heads should be marked with either three or six radial lines to designate whether grade 5 or 8 high-tensile steel was used. The threads of both the bolt and the nut should not be damaged, and the nut should run hand freely up and down the bolt. The diameter of the bolt should be 5/8 inch.

BACKUP CLAMP

The backup clamp is made to the same specifications as the lifting clamp. The backup clamp is installed above and snugly against the lifting clamp. Its purpose is to provide additional clamping and/or holding in the unlikely event that the lifting clamp should permit mast or periscope assembly slippage.

SAFTEY CLAMP

Installation of two clamps is a mandatory requirement whenever personnel are working around or beneath masts or periscopes. In these instances, the lifting and backup clamps are referred to as safety clamps.

SAFETY PRECAUTIONS

To ensure safety of equipment and personnel, the following precautions should be followed prior to the commencement of work:

1. Set up a sound-powered telephone circuit.
2. Station personnel in the following areas:

   a. On top of the sail in the vicinity of the mast being worked on.
   b. Inside the sail or in the close vicinity at the base of the mast being worked on.

3. Ensure that you follow the *Navy Safety Manual* concerning people working aloft.

NOTE: To ensure the movement of an antenna and/or periscope mast assembly is under positive control, you must have personnel stationed as specified and you must be in direct phone communications with the control valve operator in the control room.

4. Shut down (raise) and safety tag all radio/radar transmitters and close (lower) and safety tag all hoist cylinder hull stop valves of all other masts in the fairwater while personnel are working on or conducting tests and inspections.

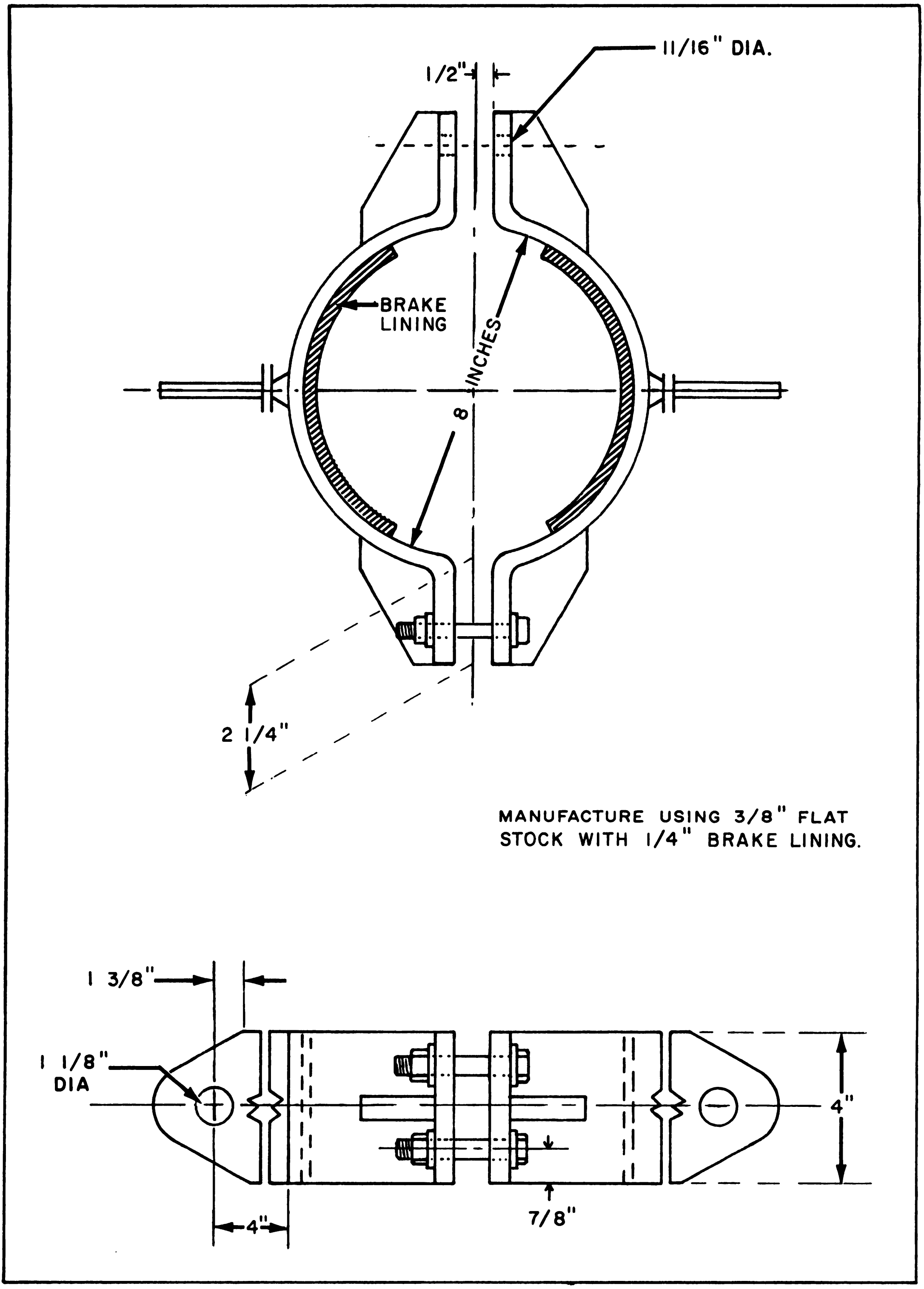

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Figure 7-1.—Hosting clamp.

The periscope bearings must be covered and protected when work is done on other apparatus (mast or antennas) in the fairwater area. This must be done to prevent entry of foreign matter that could score the periscope barrel.

CAUTION

At each repositioning of the periscope, working personnel must first be cleared from the fairwater, the periscope repositioned, and the control valve tagged out. Personnel are then repositioned to continue their work.

Before attaching the applicable lifting and backup clamps, always use the built-in hydraulic hoist assembly to place the periscope in the required position to be worked on or removed.

After the lifting clamp has been assembled on the periscope, place the control valve in the down position. This position allows the full weight of the periscope assembly to be restrained by the lifting clamp.

If no slippage of the mast or periscope assembly is observed through the lifting clamp, attach the backup clamp above and snugly against the lifting clamp. Never disconnect lifting and backup clamps or remove supportive shoring from a periscope assembly before first ensuring that a positive means of supporting the periscope's full weight is secured; that is, the periscope hydraulic hoist system must be re-energized; and the periscope must be supported by a crane, chain fall, or hardwood shoring until permanent support is restored.

CLAMPING PROCEDURES

Attach the lifting clamp to the periscope at the lifting point. Remember the periscope should be resting on the fairwater (sail). Torque each of the four hold-down nuts on each clamp sequentially and in uniform increments until a 60 foot-pound torque value has been attained on each bolt. Check the gap distance between each half of the clamps. This gap must measure the same on both sides. The clamp flange ends must never make metal to metal contact.

If no slippage of the periscope assembly is observed through the lifting clamp, attach and bolt the backup clamp around the outer tube of the periscope. Install the backup clamp above and snugly against the lifting clamp. Remember to rotate the backup clamp 90° with respect to the lifting clamp before securing it.

Next, attach the periscope lifting slings to the lifting clamp (bottom clamp). Ensure that the lifting slings are long enough to clear the periscope head. Also ensure that the lifting slings are attached to a spreader bar wide enough to keep the slings from fouling the periscope head.

At this point in the procedure, the periscope is ready for lifting. However, you must refer to applicable ship's drawings and periscope technical manuals for hydraulic disconnection and interference removal prior to lifting the periscope. The procedures for removing or reinstalling periscopes are described in OM 3 & 2, chapter 12. Refer to this publication for details.

SUBSAFE

Before you clamp a periscope for removal, you must complete all the necessary paperwork. This is a long and tedious job, but one that is necessary to protect the submarine's hull integrity. The completion of paperwork ensures that all appropriate instructions were followed in making repairs.

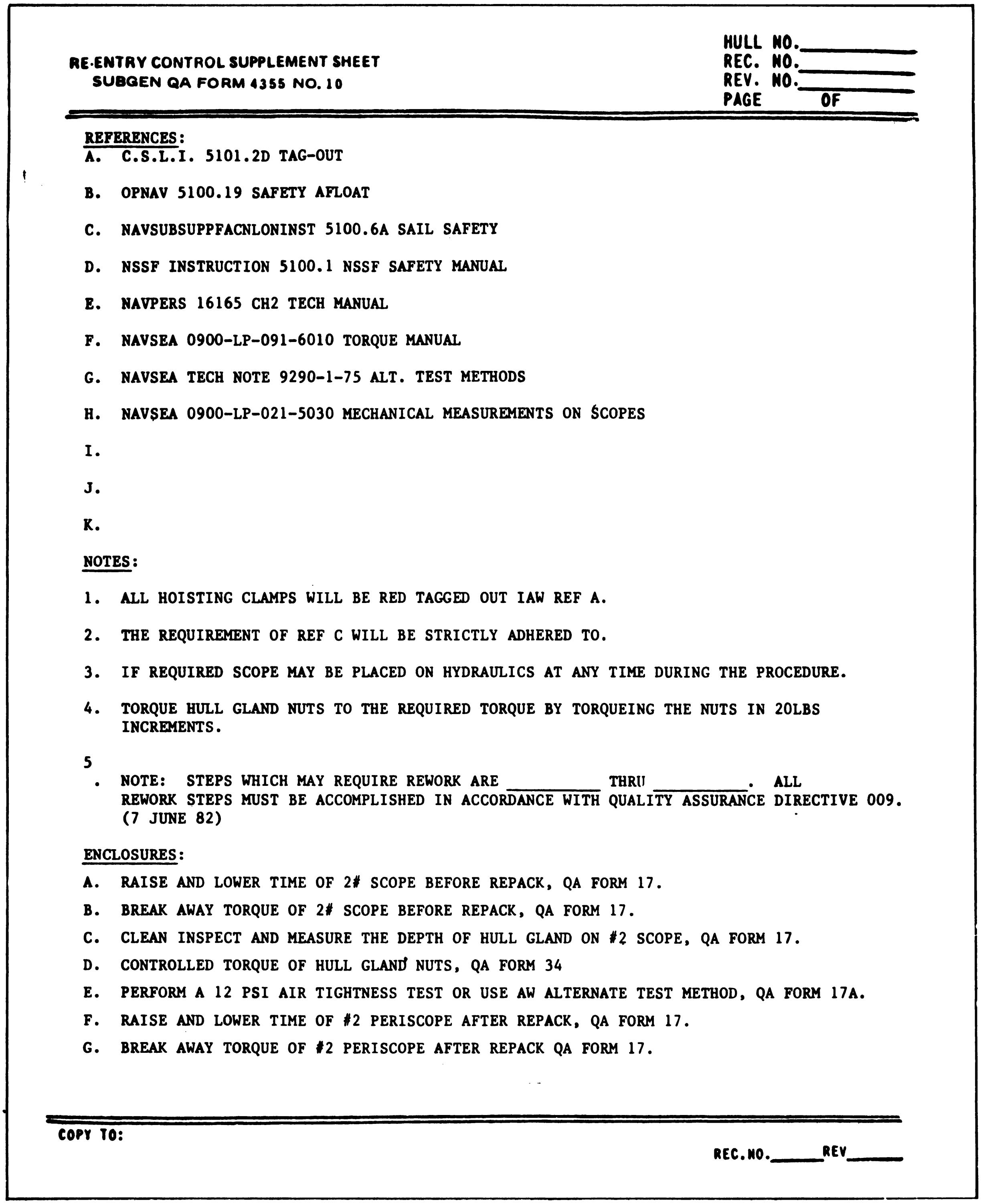
Re-entry Control Forms (QA Form 10)

You will need two re-entry QA forms. You will complete one QA form 10 for pulling and reinstalling the periscope from the submarine and another QA Form 10 for disassembling and reassembling the periscope. The QA Form 10 (fig. 7-2A through 7-2E) may consist of more than one page.

Pulling the Periscope

The QA Form 10 that must be completed when you remove the periscope is shown in figure 7-2A. It consists of four basic sections. The first is the reference section. This is the list of publications that describe how the job is to be completed. It includes safety and testing procedures. The second section is a listing of notes that call attention to specific safety factors and/or procedures that will require extra attention. Note 5 (fig. 7-2A) contains spaces to list the steps necessary to rework any part of a job that fails to pass a particular test. The third section lists all of the enclosures that are combined with the QA Form 10 to make up the QA package.

Section 4 of the QA Form 10 (fig. 7-2B through fig. 7-2E) lists all the steps required to complete the job. Each step requires one or more



RE-ENTRY CONTROL SUPPLEMENT SHEET
SUBGEN QA FORM 4355 NO. 10

HULL NO.__________
REC. NO.__________
REV. NO.__________
PAGE ____ OF ____

REFERENCES:

A. C.S.L.I. 5101.2D TAG-OUT

B. OPNAV 5100.19 SAFETY AFLOAT

C. NAVSUBSUPPFACNLONINST 5100.6A SAIL SAFETY

D. NSSF INSTRUCTION 5100.1 NSSF SAFETY MANUAL

E. NAVPERS 16165 CH2 TECH MANUAL

F. NAVSEA 0900-LP-091-6010 TORQUE MANUAL

G. NAVSEA TECH NOTE 9290-1-75 ALT. TEST METHODS

H. NAVSEA 0900-LP-021-5030 MECHANICAL MEASUREMENTS ON SCOPES

I.

J.

K.

NOTES:

1. ALL HOISTING CLAMPS WILL BE RED TAGGED OUT IAW REF A.

2. THE REQUIREMENT OF REF C WILL BE STRICTLY ADHERED TO.

3. IF REQUIRED SCOPE MAY BE PLACED ON HYDRAULICS AT ANY TIME DURING THE PROCEDURE.

4. TORQUE HULL GLAND NUTS TO THE REQUIRED TORQUE BY TORQUEING THE NUTS IN 20LBS INCREMENTS.

5. NOTE: STEPS WHICH MAY REQUIRE REWORK ARE __________ THRU __________. ALL REWORK STEPS MUST BE ACCOMPLISHED IN ACCORDANCE WITH QUALITY ASSURANCE DIRECTIVE 009. (7 JUNE 82)

ENCLOSURES:

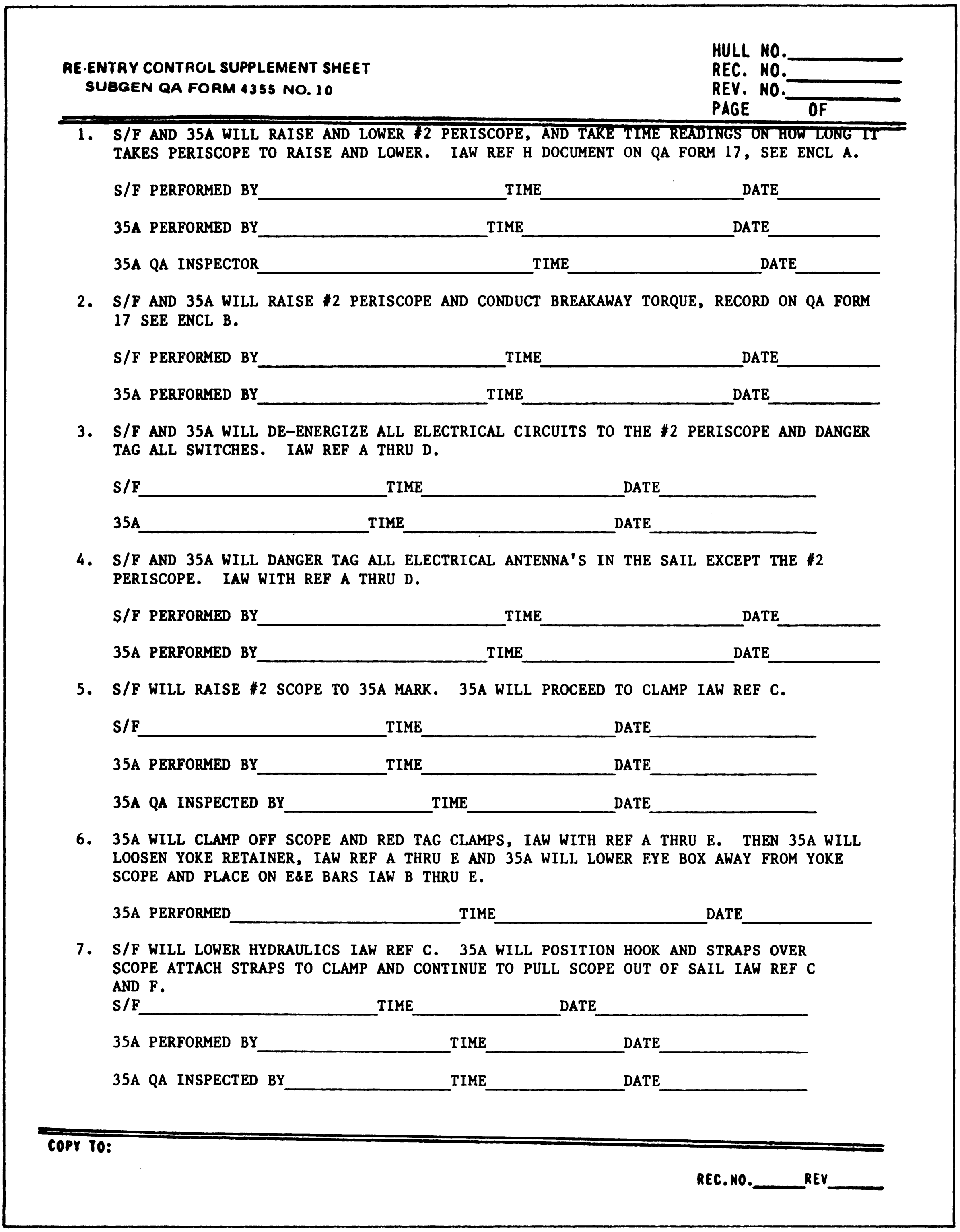
A. RAISE AND LOWER TIME OF 2# SCOPE BEFORE REPACK, QA FORM 17.
B. BREAK AWAY TORQUE OF 2# SCOPE BEFORE REPACK, QA FORM 17.
C. CLEAN INSPECT AND MEASURE THE DEPTH OF HULL GLAND ON #2 SCOPE, QA FORM 17.
D. CONTROLLED TORQUE OF HULL GLAND NUTS, QA FORM 34
E. PERFORM A 12 PSI AIR TIGHTNESS TEST OR USE AW ALTERNATE TEST METHOD, QA FORM 17A.
F. RAISE AND LOWER TIME OF #2 PERISCOPE AFTER REPACK, QA FORM 17.
G. BREAK AWAY TORQUE OF #2 PERISCOPE AFTER REPACK QA FORM 17.

COPY TO:

REC.NO.______ REV______

148.415

Figure 7-2A.—QA Form 10 Re-entry Control Supplement Sheet part 1.



HULL NO.________
REC. NO.________
REV. NO.________
PAGE ___ OF ___

RE-ENTRY CONTROL SUPPLEMENT SHEET
SUBGEN QA FORM 4355 NO. 10

1. S/F AND 35A WILL RAISE AND LOWER #2 PERISCOPE, AND TAKE TIME READINGS ON HOW LONG IT TAKES PERISCOPE TO RAISE AND LOWER. IAW REF H DOCUMENT ON QA FORM 17, SEE ENCL A.

S/F PERFORMED BY________________TIME________________DATE________

35A PERFORMED BY________________TIME________________DATE________

35A QA INSPECTOR________________TIME________________DATE________

2. S/F AND 35A WILL RAISE #2 PERISCOPE AND CONDUCT BREAKAWAY TORQUE, RECORD ON QA FORM 17 SEE ENCL B.

S/F PERFORMED BY________________TIME________________DATE________

35A PERFORMED BY________________TIME________________DATE________

3. S/F AND 35A WILL DE-ENERGIZE ALL ELECTRICAL CIRCUITS TO THE #2 PERISCOPE AND DANGER TAG ALL SWITCHES. IAW REF A THRU D.

S/F________________TIME________________DATE________

35A________________TIME________________DATE________

4. S/F AND 35A WILL DANGER TAG ALL ELECTRICAL ANTENNA'S IN THE SAIL EXCEPT THE #2 PERISCOPE. IAW WITH REF A THRU D.

S/F PERFORMED BY________________TIME________________DATE________

35A PERFORMED BY________________TIME________________DATE________

5. S/F WILL RAISE #2 SCOPE TO 35A MARK. 35A WILL PROCEED TO CLAMP IAW REF C.

S/F________________TIME________________DATE________

35A PERFORMED BY________TIME________________DATE________

35A QA INSPECTED BY________TIME________DATE________

6. 35A WILL CLAMP OFF SCOPE AND RED TAG CLAMPS, IAW WITH REF A THRU E. THEN 35A WILL LOOSEN YOKE RETAINER, IAW REF A THRU E AND 35A WILL LOWER EYE BOX AWAY FROM YOKE SCOPE AND PLACE ON E&E BARS IAW B THRU E.

35A PERFORMED________________TIME________________DATE________

7. S/F WILL LOWER HYDRAULICS IAW REF C. 35A WILL POSITION HOOK AND STRAPS OVER SCOPE ATTACH STRAPS TO CLAMP AND CONTINUE TO PULL SCOPE OUT OF SAIL IAW REF C AND F.

S/F________________TIME________DATE________

35A PERFORMED BY________TIME________DATE________

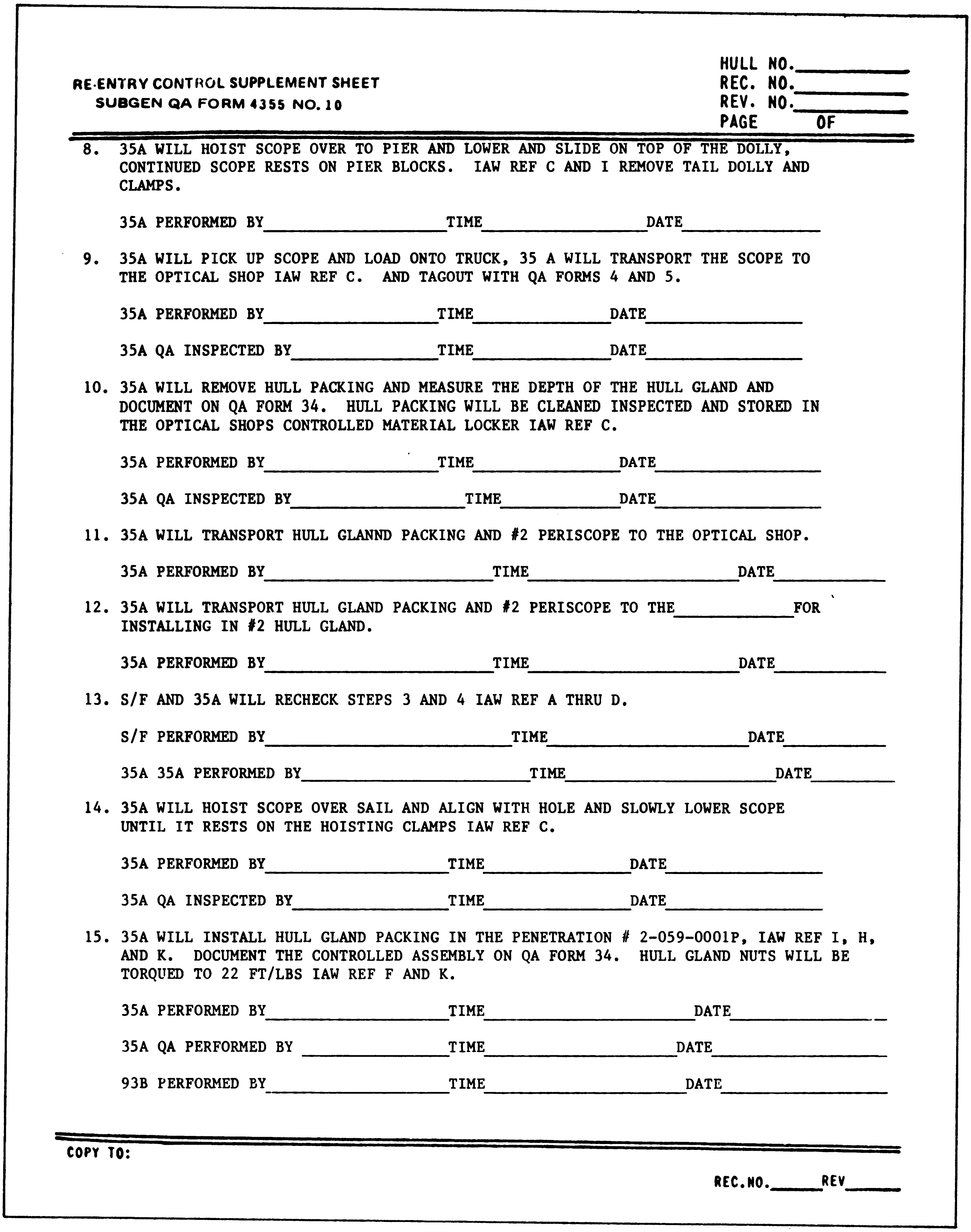
35A QA INSPECTED BY________TIME________DATE________

COPY TO:

REC.NO.______REV______

148.415.1

Figure 7-2B.—QA Form 10 Re-entry Control Supplement Sheet part 2.



RE-ENTRY CONTROL SUPPLEMENT SHEET
SUBGEN QA FORM 4355 NO. 10

HULL NO.________
REC. NO.________
REV. NO.________
PAGE ____ OF ____

8. 35A WILL HOIST SCOPE OVER TO PIER AND LOWER AND SLIDE ON TOP OF THE DOLLY, CONTINUED SCOPE RESTS ON PIER BLOCKS. IAW REF C AND I REMOVE TAIL DOLLY AND CLAMPS.

35A PERFORMED BY________TIME________DATE________

9. 35A WILL PICK UP SCOPE AND LOAD ONTO TRUCK, 35 A WILL TRANSPORT THE SCOPE TO THE OPTICAL SHOP IAW REF C. AND TAGOUT WITH QA FORMS 4 AND 5.

35A PERFORMED BY________TIME________DATE________

35A QA INSPECTED BY________TIME________DATE________

10. 35A WILL REMOVE HULL PACKING AND MEASURE THE DEPTH OF THE HULL GLAND AND DOCUMENT ON QA FORM 34. HULL PACKING WILL BE CLEANED INSPECTED AND STORED IN THE OPTICAL SHOPS CONTROLLED MATERIAL LOCKER IAW REF C.

35A PERFORMED BY________TIME________DATE________

35A QA INSPECTED BY________TIME________DATE________

11. 35A WILL TRANSPORT HULL GLANND PACKING AND #2 PERISCOPE TO THE OPTICAL SHOP.

35A PERFORMED BY________TIME________DATE________

12. 35A WILL TRANSPORT HULL GLAND PACKING AND #2 PERISCOPE TO THE________FOR INSTALLING IN #2 HULL GLAND.

35A PERFORMED BY________TIME________DATE________

13. S/F AND 35A WILL RECHECK STEPS 3 AND 4 IAW REF A THRU D.

S/F PERFORMED BY________TIME________DATE________

35A 35A PERFORMED BY________TIME________DATE________

14. 35A WILL HOIST SCOPE OVER SAIL AND ALIGN WITH HOLE AND SLOWLY LOWER SCOPE UNTIL IT RESTS ON THE HOISTING CLAMPS IAW REF C.

35A PERFORMED BY________TIME________DATE________

35A QA INSPECTED BY________TIME________DATE________

15. 35A WILL INSTALL HULL GLAND PACKING IN THE PENETRATION # 2-059-0001P, IAW REF I, H, AND K. DOCUMENT THE CONTROLLED ASSEMBLY ON QA FORM 34. HULL GLAND NUTS WILL BE TORQUED TO 22 FT/LBS IAW REF F AND K.

35A PERFORMED BY________TIME________DATE________

35A QA PERFORMED BY ________TIME________DATE________

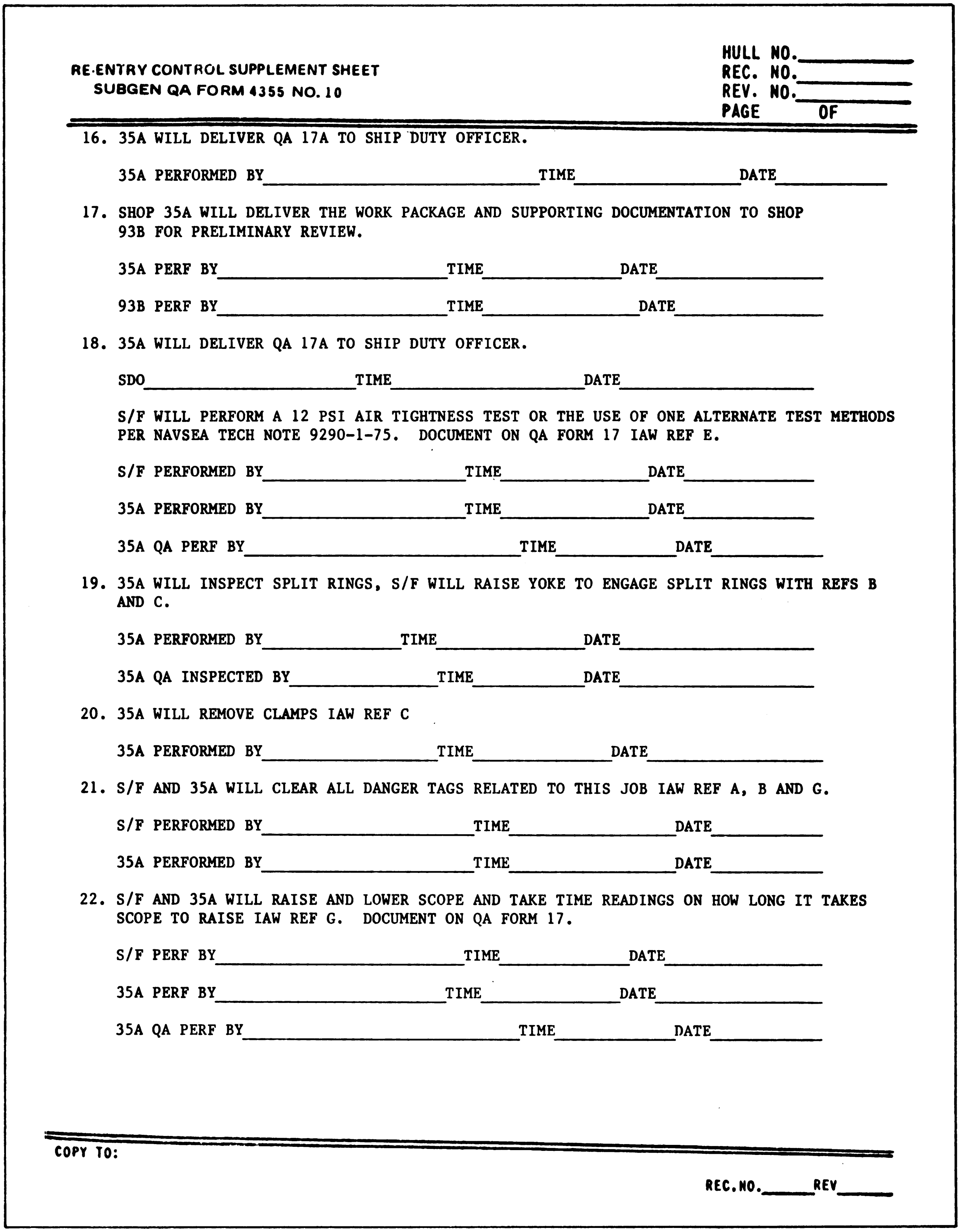
93B PERFORMED BY________TIME________DATE________

COPY TO:

REC.NO.______REV______

148.415.2

Figure 7-2C.—QA Form 10 Re-entry Control Supplement Sheet part 3.



RE-ENTRY CONTROL SUPPLEMENT SHEET
SUBGEN QA FORM 4355 NO. 10

HULL NO.__________
REC. NO.__________
REV. NO.__________
PAGE ____ OF ____

16. 35A WILL DELIVER QA 17A TO SHIP DUTY OFFICER.

35A PERFORMED BY__________ TIME__________ DATE__________

17. SHOP 35A WILL DELIVER THE WORK PACKAGE AND SUPPORTING DOCUMENTATION TO SHOP 93B FOR PRELIMINARY REVIEW.

35A PERF BY__________ TIME__________ DATE__________

93B PERF BY__________ TIME__________ DATE__________

18. 35A WILL DELIVER QA 17A TO SHIP DUTY OFFICER.

SDO__________ TIME__________ DATE__________

S/F WILL PERFORM A 12 PSI AIR TIGHTNESS TEST OR THE USE OF ONE ALTERNATE TEST METHODS PER NAVSEA TECH NOTE 9290-1-75. DOCUMENT ON QA FORM 17 IAW REF E.

S/F PERFORMED BY__________ TIME__________ DATE__________

35A PERFORMED BY__________ TIME__________ DATE__________

35A QA PERF BY__________ TIME__________ DATE__________

19. 35A WILL INSPECT SPLIT RINGS, S/F WILL RAISE YOKE TO ENGAGE SPLIT RINGS WITH REFS B AND C.

35A PERFORMED BY__________ TIME__________ DATE__________

35A QA INSPECTED BY__________ TIME__________ DATE__________

20. 35A WILL REMOVE CLAMPS IAW REF C

35A PERFORMED BY__________ TIME__________ DATE__________

21. S/F AND 35A WILL CLEAR ALL DANGER TAGS RELATED TO THIS JOB IAW REF A, B AND G.

S/F PERFORMED BY__________ TIME__________ DATE__________

35A PERFORMED BY__________ TIME__________ DATE__________

22. S/F AND 35A WILL RAISE AND LOWER SCOPE AND TAKE TIME READINGS ON HOW LONG IT TAKES SCOPE TO RAISE IAW REF G. DOCUMENT ON QA FORM 17.

S/F PERF BY__________ TIME__________ DATE__________

35A PERF BY__________ TIME__________ DATE__________

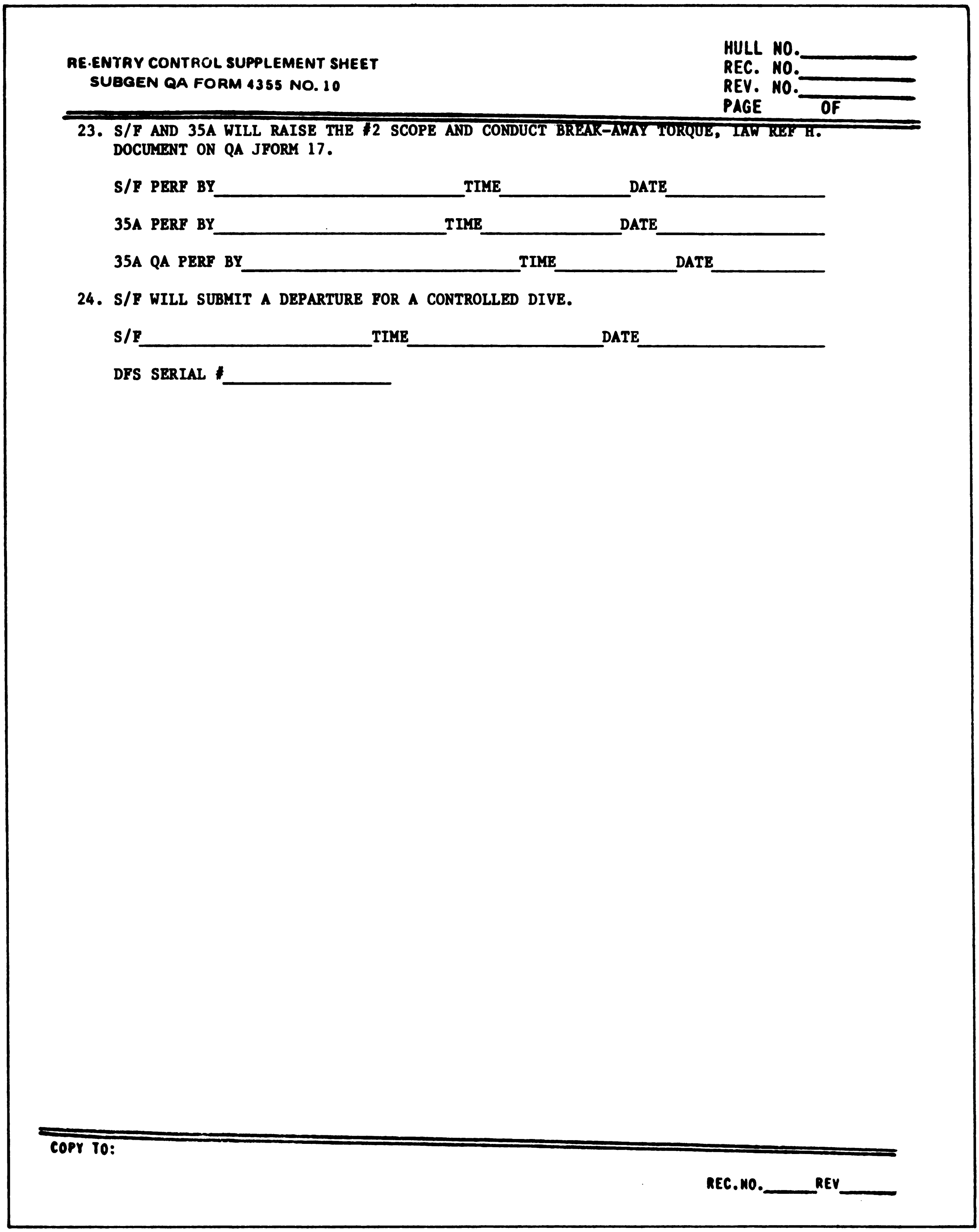
35A QA PERF BY__________ TIME__________ DATE__________

COPY TO:

REC.NO.______ REV______

148.415.3

Figure 7-2D.—QA Form 10 Re-entry Control Supplement Sheet part 4.



RE-ENTRY CONTROL SUPPLEMENT SHEET
SUBGEN QA FORM 4355 NO. 10

HULL NO.__________
REC. NO.__________
REV. NO.__________
PAGE OF

23. S/F AND 35A WILL RAISE THE #2 SCOPE AND CONDUCT BREAK-AWAY TORQUE, IAW REF H. DOCUMENT ON QA JFORM 17.

S/F PERF BY____________________ TIME__________ DATE__________

35A PERF BY____________________ TIME__________ DATE__________

35A QA PERF BY____________________ TIME__________ DATE__________

24. S/F WILL SUBMIT A DEPARTURE FOR A CONTROLLED DIVE.

S/F____________________ TIME__________ DATE__________

DFS SERIAL #_______________

COPY TO:

REC.NO._____ REV_____

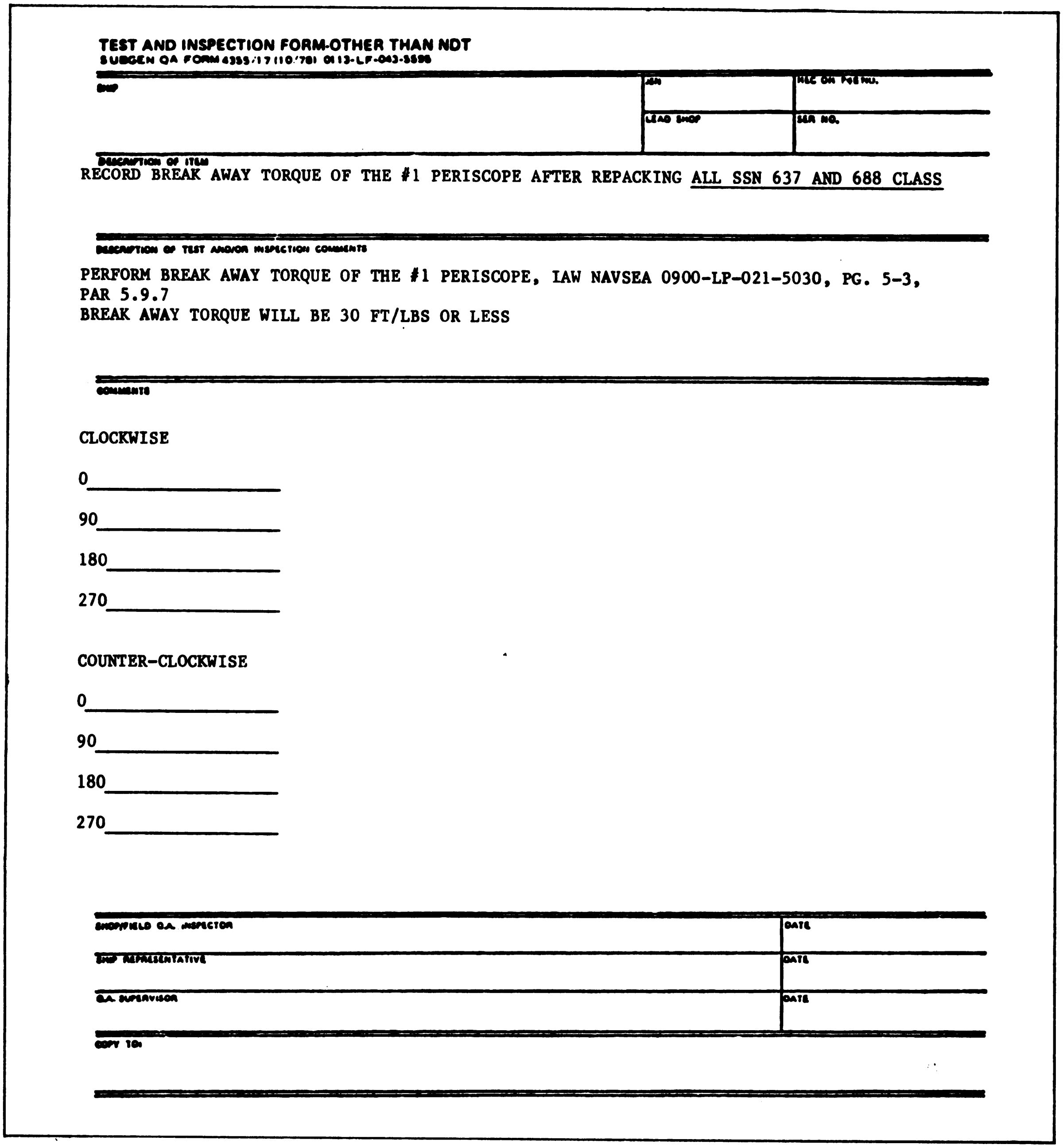
148.415.4

Figure 7-2E.—QA Form 10 Re-entry Control Supplement Sheet part 5.

signatures in addition to the time and date when each step was completed. Some steps require the signature of the senior opticalman assigned to the job. Other steps require the additional signature of the optical shop quality assurance (QA) inspector.

The shop QA inspector, designated in writing, is trained to perform that shop's function. The shop QA inspector and the person who signs the "PERFORMED BY" line cannot be the same person, even though the QA inspector may be the senior person assigned to the shop. In such cases, the next senior person must sign the "PERFORMED BY" line. Some steps must be witnessed and signed by the ship's force, and some tests must be witnessed and signed by the repair department's QA inspector. All QA forms must be completed and signed in the proper sequence.

Figure 7-3 is an example of an QA Form 17 and figure 7-4 is an example of a QA Form 34.



TEST AND INSPECTION FORM-OTHER THAN NDT
SUBGEN QA FORM 4355/17 (10/78) 0113-LF-043-5595

SHIP	JSN	MIC OR PGE NO.
	LEAD SHOP	SER NO.

DESCRIPTION OF ITEM
RECORD BREAK AWAY TORQUE OF THE #1 PERISCOPE AFTER REPACKING ALL SSN 637 AND 688 CLASS

DESCRIPTION OF TEST AND/OR INSPECTION COMMENTS
PERFORM BREAK AWAY TORQUE OF THE #1 PERISCOPE, IAW NAVSEA 0900-LP-021-5030, PG. 5-3, PAR 5.9.7
BREAK AWAY TORQUE WILL BE 30 FT/LBS OR LESS

COMMENTS

CLOCKWISE

0______________

90______________

180______________

270______________

COUNTER-CLOCKWISE

0______________

90______________

180______________

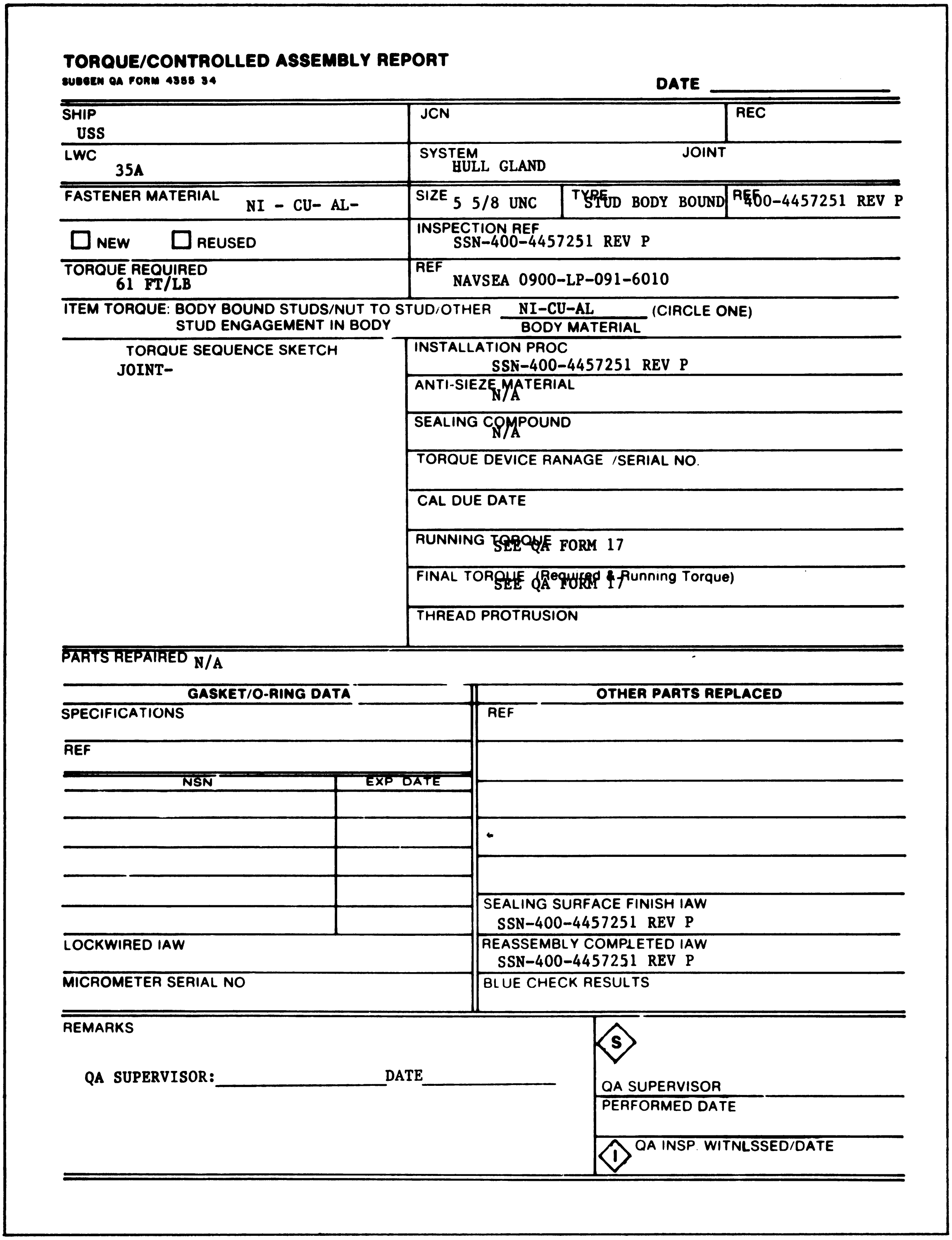
270______________

SHOP/FIELD Q.A. INSPECTOR	DATE
SHIP REPRESENTATIVE	DATE
Q.A. SUPERVISOR	DATE

COPY TO:

148.416

Figure 7-3.—QA Form 17 Test and Inspection Form Other Than NDT.



TORQUE/CONTROLLED ASSEMBLY REPORT

SUBGEN QA FORM 4355 34

DATE ______________

SHIP USS	JCN	REC
LWC 35A	SYSTEM HULL GLAND	JOINT

FASTENER MATERIAL NI - CU- AL-	SIZE 5 5/8 UNC	TYPE STUD BODY BOUND	REF 400-4457251 REV P
☐ NEW ☐ REUSED	INSPECTION REF SSN-400-4457251 REV P		
TORQUE REQUIRED 61 FT/LB	REF NAVSEA 0900-LP-091-6010		

ITEM TORQUE: BODY BOUND STUDS/NUT TO STUD/OTHER NI-CU-AL (CIRCLE ONE)
STUD ENGAGEMENT IN BODY BODY MATERIAL

TORQUE SEQUENCE SKETCH JOINT-	INSTALLATION PROC SSN-400-4457251 REV P
	ANTI-SIEZE MATERIAL N/A
	SEALING COMPOUND N/A
	TORQUE DEVICE RANAGE /SERIAL NO.
	CAL DUE DATE
	RUNNING TORQUE SEE QA FORM 17
	FINAL TORQUE (Required & Running Torque) SEE QA FORM 17
	THREAD PROTRUSION

PARTS REPAIRED N/A

GASKET/O-RING DATA		OTHER PARTS REPLACED
SPECIFICATIONS		REF
REF		
NSN	EXP DATE	
		SEALING SURFACE FINISH IAW SSN-400-4457251 REV P
LOCKWIRED IAW		REASSEMBLY COMPLETED IAW SSN-400-4457251 REV P
MICROMETER SERIAL NO		BLUE CHECK RESULTS

REMARKS QA SUPERVISOR:__________ DATE__________	S QA SUPERVISOR
	PERFORMED DATE
	I QA INSP. WITNESSED/DATE

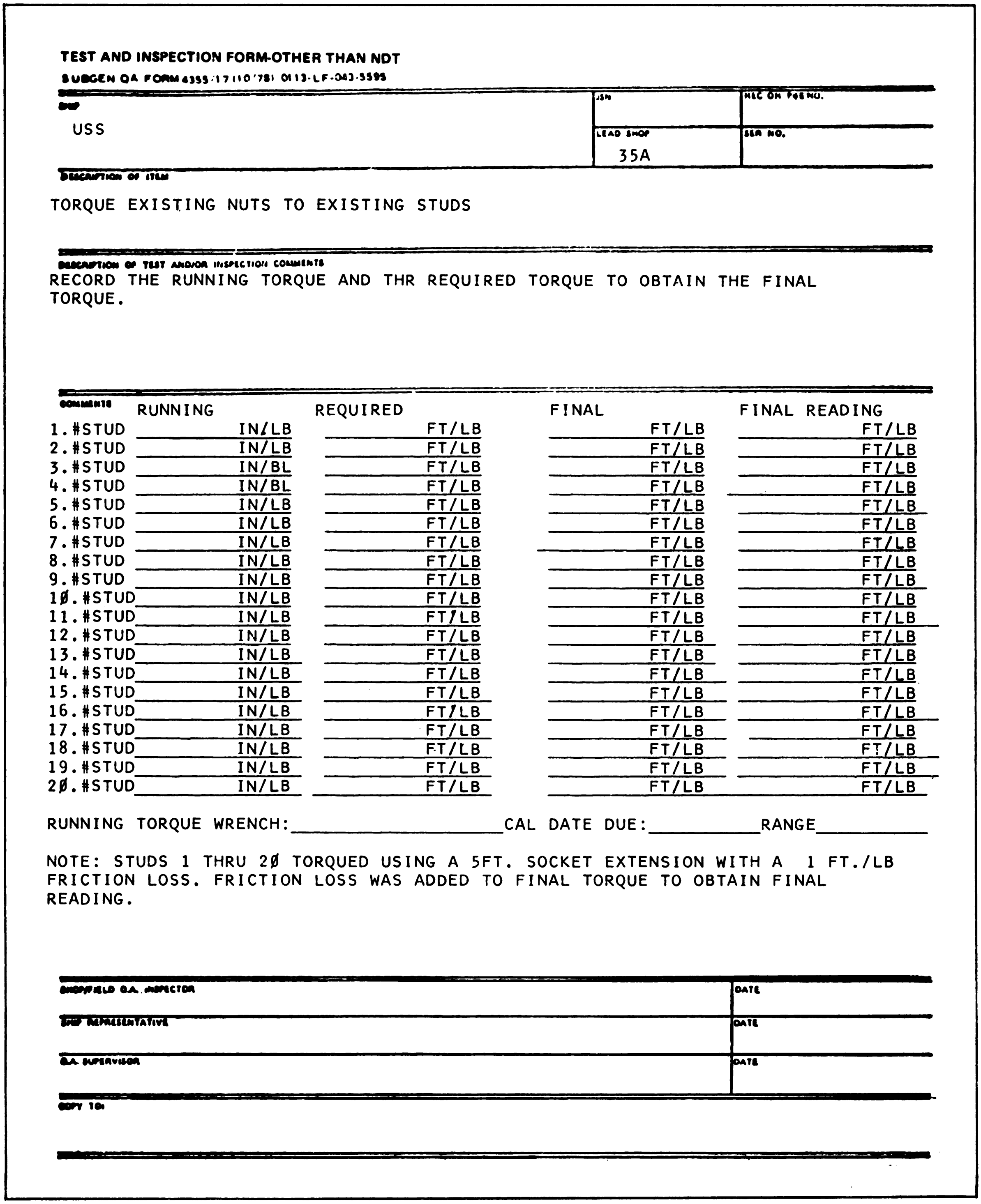
148.417

Figure 7-4.—QA Form 34 Torque/Controlled Assembly Report.

These two forms are listed in section 3 of the QA Form 10 (fig. 7-2A).

QA Form 17 (fig.7-3) is a test and inspection form. It lists all the tests and inspections that must be performed at each step. A QA Form 17 must be completed and signed before any step can be signed off on the QA Form 10.

QA Form 34 (fig. 7-4) is a torque/controlled assembly report. It consists of two enclosures: the torque sequence sketch and a QA Form 17 (fig. 7-5) listing all of the required torque readings.



TEST AND INSPECTION FORM-OTHER THAN NDT

SUBGEN QA FORM 4355/17 (10'78) 0113-LF-043-5595

SHIP USS	JSN	HLC OR P&E NO.
	LEAD SHOP 35A	SER NO.

DESCRIPTION OF ITEM

TORQUE EXISTING NUTS TO EXISTING STUDS

DESCRIPTION OF TEST AND/OR INSPECTION COMMENTS

RECORD THE RUNNING TORQUE AND THR REQUIRED TORQUE TO OBTAIN THE FINAL TORQUE.

COMMENTS	RUNNING	REQUIRED	FINAL	FINAL READING
1.#STUD	IN/LB	FT/LB	FT/LB	FT/LB
2.#STUD	IN/LB	FT/LB	FT/LB	FT/LB
3.#STUD	IN/BL	FT/LB	FT/LB	FT/LB
4.#STUD	IN/BL	FT/LB	FT/LB	FT/LB
5.#STUD	IN/LB	FT/LB	FT/LB	FT/LB
6.#STUD	IN/LB	FT/LB	FT/LB	FT/LB
7.#STUD	IN/LB	FT/LB	FT/LB	FT/LB
8.#STUD	IN/LB	FT/LB	FT/LB	FT/LB
9.#STUD	IN/LB	FT/LB	FT/LB	FT/LB
10.#STUD	IN/LB	FT/LB	FT/LB	FT/LB
11.#STUD	IN/LB	FT/LB	FT/LB	FT/LB
12.#STUD	IN/LB	FT/LB	FT/LB	FT/LB
13.#STUD	IN/LB	FT/LB	FT/LB	FT/LB
14.#STUD	IN/LB	FT/LB	FT/LB	FT/LB
15.#STUD	IN/LB	FT/LB	FT/LB	FT/LB
16.#STUD	IN/LB	FT/LB	FT/LB	FT/LB
17.#STUD	IN/LB	FT/LB	FT/LB	FT/LB
18.#STUD	IN/LB	FT/LB	FT/LB	FT/LB
19.#STUD	IN/LB	FT/LB	FT/LB	FT/LB
20.#STUD	IN/LB	FT/LB	FT/LB	FT/LB

RUNNING TORQUE WRENCH:____________________CAL DATE DUE:___________RANGE___________

NOTE: STUDS 1 THRU 20 TORQUED USING A 5FT. SOCKET EXTENSION WITH A 1 FT./LB FRICTION LOSS. FRICTION LOSS WAS ADDED TO FINAL TORQUE TO OBTAIN FINAL READING.

SHOP/FIELD Q.A. INSPECTOR	DATE
SHIP REPRESENTATIVE	DATE
Q.A. SUPERVISOR	DATE

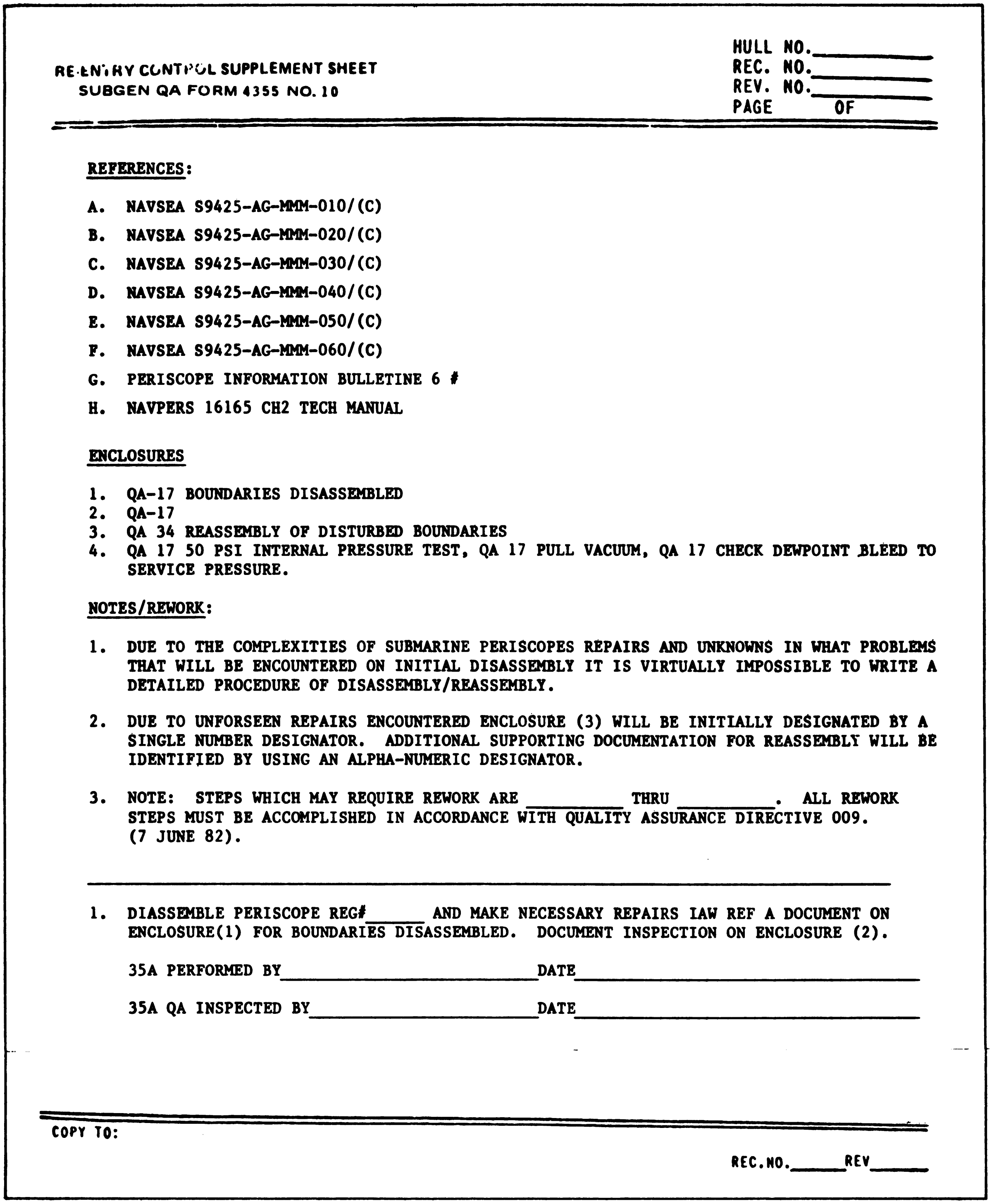
COPY TO:

148.418

Figure 7-5.—QA Form 34 Test and Inspection Form Other Than NDT.

Disassembly of the Periscope

The QA Form 10 shown in figure 7-6A is also used in disassembly and reassembly of the periscope. This form also must show the periscope references, enclosures, notes, and the critical steps required to complete the job (fig. 7-6A and 6B). All boundaries that may be disturbed during disassembly and repair of the periscope are described in QA Form 17 as shown in



RE-ENTRY CONTROL SUPPLEMENT SHEET
SUBGEN QA FORM 4355 NO. 10

HULL NO.__________
REC. NO.__________
REV. NO.__________
PAGE OF

REFERENCES:

A. NAVSEA S9425-AG-MMM-010/(C)
B. NAVSEA S9425-AG-MMM-020/(C)
C. NAVSEA S9425-AG-MMM-030/(C)
D. NAVSEA S9425-AG-MMM-040/(C)
E. NAVSEA S9425-AG-MMM-050/(C)
F. NAVSEA S9425-AG-MMM-060/(C)
G. PERISCOPE INFORMATION BULLETINE 6 #
H. NAVPERS 16165 CH2 TECH MANUAL

ENCLOSURES

1. QA-17 BOUNDARIES DISASSEMBLED
2. QA-17
3. QA 34 REASSEMBLY OF DISTURBED BOUNDARIES
4. QA 17 50 PSI INTERNAL PRESSURE TEST, QA 17 PULL VACUUM, QA 17 CHECK DEWPOINT BLEED TO SERVICE PRESSURE.

NOTES/REWORK:

1. DUE TO THE COMPLEXITIES OF SUBMARINE PERISCOPES REPAIRS AND UNKNOWNS IN WHAT PROBLEMS THAT WILL BE ENCOUNTERED ON INITIAL DISASSEMBLY IT IS VIRTUALLY IMPOSSIBLE TO WRITE A DETAILED PROCEDURE OF DISASSEMBLY/REASSEMBLY.

2. DUE TO UNFORSEEN REPAIRS ENCOUNTERED ENCLOSURE (3) WILL BE INITIALLY DESIGNATED BY A SINGLE NUMBER DESIGNATOR. ADDITIONAL SUPPORTING DOCUMENTATION FOR REASSEMBLY WILL BE IDENTIFIED BY USING AN ALPHA-NUMERIC DESIGNATOR.

3. NOTE: STEPS WHICH MAY REQUIRE REWORK ARE __________ THRU __________. ALL REWORK STEPS MUST BE ACCOMPLISHED IN ACCORDANCE WITH QUALITY ASSURANCE DIRECTIVE 009. (7 JUNE 82).

1. DIASSEMBLE PERISCOPE REG#______ AND MAKE NECESSARY REPAIRS IAW REF A DOCUMENT ON ENCLOSURE(1) FOR BOUNDARIES DISASSEMBLED. DOCUMENT INSPECTION ON ENCLOSURE (2).

35A PERFORMED BY____________________DATE____________________

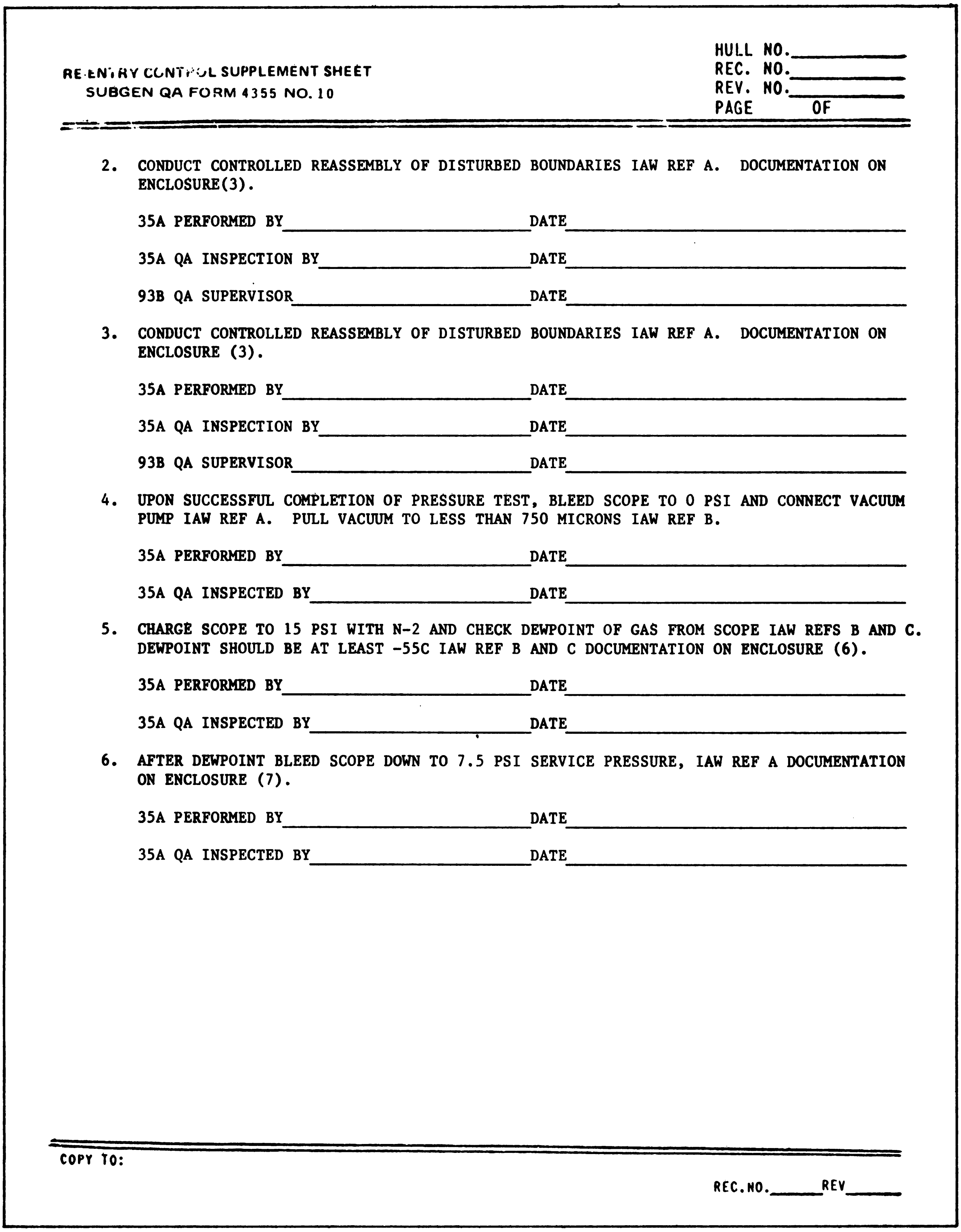
35A QA INSPECTED BY____________________DATE____________________

COPY TO:

REC.NO.______REV______

148.419

Figure 7-6A.—QA Form 10 Re-entry Control Supplement Sheet part 1.



RE-ENTRY CONTROL SUPPLEMENT SHEET
SUBGEN QA FORM 4355 NO. 10

HULL NO.______
REC. NO.______
REV. NO.______
PAGE OF

2. CONDUCT CONTROLLED REASSEMBLY OF DISTURBED BOUNDARIES IAW REF A. DOCUMENTATION ON ENCLOSURE(3).

35A PERFORMED BY______ DATE______

35A QA INSPECTION BY______ DATE______

93B QA SUPERVISOR______ DATE______

3. CONDUCT CONTROLLED REASSEMBLY OF DISTURBED BOUNDARIES IAW REF A. DOCUMENTATION ON ENCLOSURE (3).

35A PERFORMED BY______ DATE______

35A QA INSPECTION BY______ DATE______

93B QA SUPERVISOR______ DATE______

4. UPON SUCCESSFUL COMPLETION OF PRESSURE TEST, BLEED SCOPE TO 0 PSI AND CONNECT VACUUM PUMP IAW REF A. PULL VACUUM TO LESS THAN 750 MICRONS IAW REF B.

35A PERFORMED BY______ DATE______

35A QA INSPECTED BY______ DATE______

5. CHARGE SCOPE TO 15 PSI WITH N-2 AND CHECK DEWPOINT OF GAS FROM SCOPE IAW REFS B AND C. DEWPOINT SHOULD BE AT LEAST -55C IAW REF B AND C DOCUMENTATION ON ENCLOSURE (6).

35A PERFORMED BY______ DATE______

35A QA INSPECTED BY______ DATE______

6. AFTER DEWPOINT BLEED SCOPE DOWN TO 7.5 PSI SERVICE PRESSURE, IAW REF A DOCUMENTATION ON ENCLOSURE (7).

35A PERFORMED BY______ DATE______

35A QA INSPECTED BY______ DATE______

COPY TO:

REC.NO.______REV______

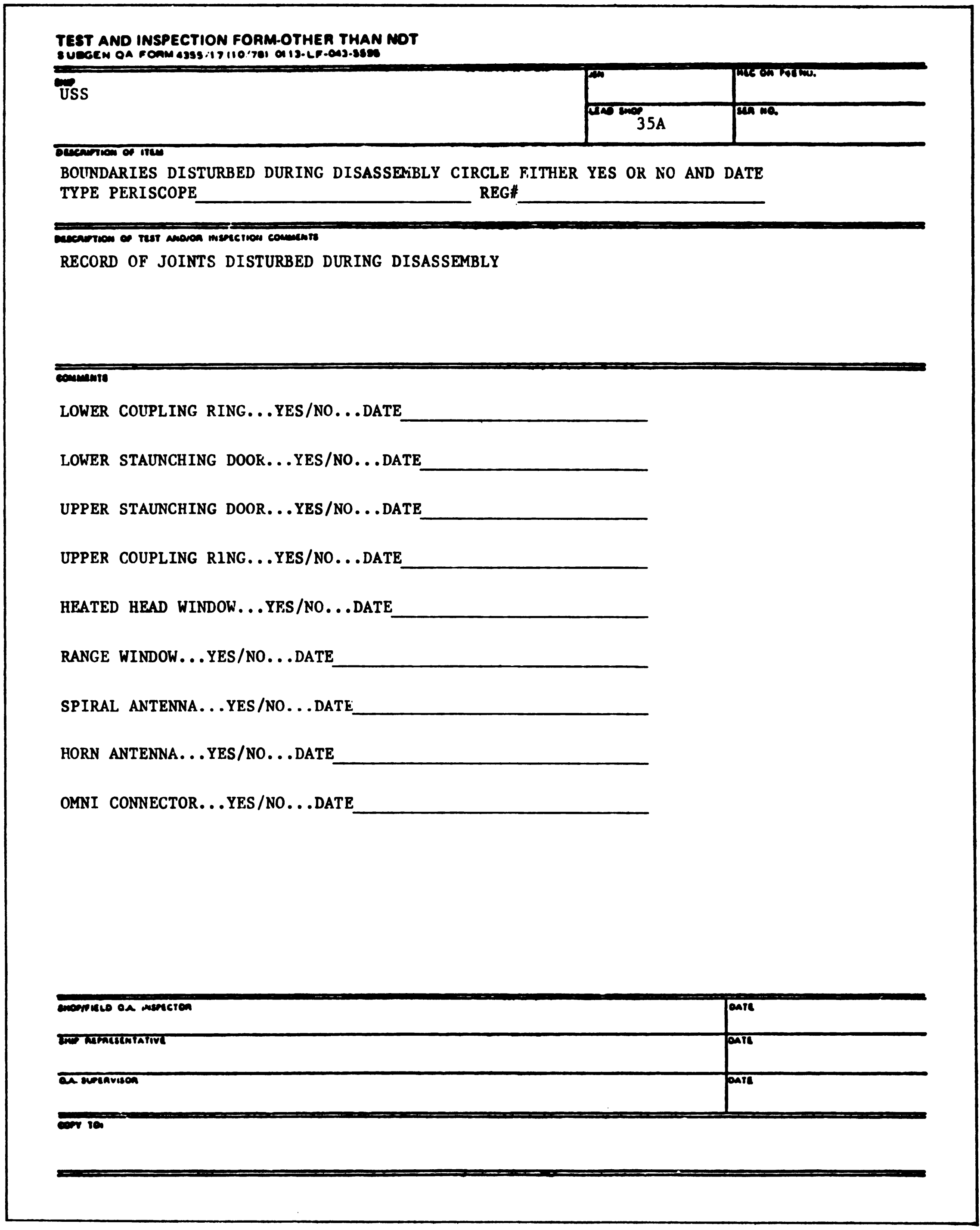
148.419.1

Figure 7-6B.—QA Form 10 Re-entry Control Supplement Sheet part 2.

fig.7-6C. You must prepare a QA Form 34 as shown in figures 7-6D, E, and F before reassembling the boundaries that are disturbed. One more QA Form 17 must be prepared when you perform the pressure test, evacuation, and dew-point check needed to put the periscope back into service.

CONTROLLED MATERIAL

Any item that supports either a SUBSAFE (SS) or level 1 (L1) system that has undergone extreme material control and quality assurance is known as controlled material. Each item has



TEST AND INSPECTION FORM-OTHER THAN NDT
SUBGEN QA FORM 4355/17 (10/78) 0113-LF-043-5595

SHIP USS	JCN	MIC OR FSE NO.
	LEAD SHOP 35A	SER NO.

DESCRIPTION OF ITEM

BOUNDARIES DISTURBED DURING DISASSEMBLY CIRCLE EITHER YES OR NO AND DATE
TYPE PERISCOPE______________________ REG#____________________

DESCRIPTION OF TEST AND/OR INSPECTION COMMENTS

RECORD OF JOINTS DISTURBED DURING DISASSEMBLY

COMMENTS

LOWER COUPLING RING...YES/NO...DATE__________________

LOWER STAUNCHING DOOR...YES/NO...DATE__________________

UPPER STAUNCHING DOOR...YES/NO...DATE__________________

UPPER COUPLING RING...YES/NO...DATE__________________

HEATED HEAD WINDOW...YES/NO...DATE__________________

RANGE WINDOW...YES/NO...DATE__________________

SPIRAL ANTENNA...YES/NO...DATE__________________

HORN ANTENNA...YES/NO...DATE__________________

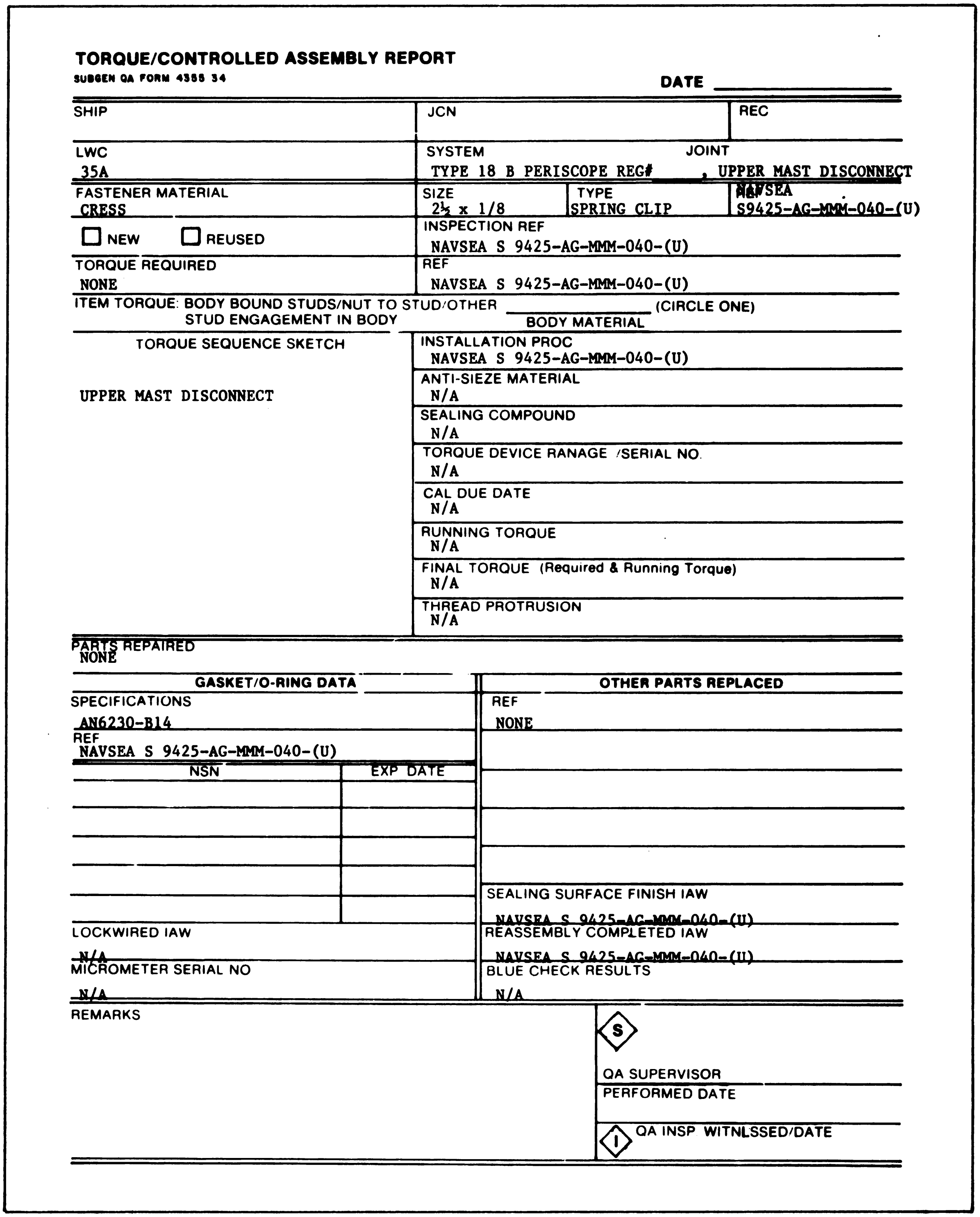
OMNI CONNECTOR...YES/NO...DATE__________________

SHOP/FIELD Q.A. INSPECTOR	DATE
SHIP REPRESENTATIVE	DATE
Q.A. SUPERVISOR	DATE

COPY TO:

148.419.2

Figure 7-6C.—QA Form 10 Test and Inspection Form Other Than NDT.



TORQUE/CONTROLLED ASSEMBLY REPORT

SUBGEN QA FORM 4355 34

DATE ____________

SHIP	JCN	REC
LWC 35A	SYSTEM TYPE 18 B PERISCOPE REG#	JOINT , UPPER MAST DISCONNECT

FASTENER MATERIAL CRESS	SIZE 2½ x 1/8	TYPE SPRING CLIP	REF NAVSEA S9425-AG-MMM-040-(U)

☐ NEW ☐ REUSED

INSPECTION REF: NAVSEA S 9425-AG-MMM-040-(U)

TORQUE REQUIRED: NONE

REF: NAVSEA S 9425-AG-MMM-040-(U)

ITEM TORQUE: BODY BOUND STUDS/NUT TO STUD/OTHER ____________ (CIRCLE ONE)

STUD ENGAGEMENT IN BODY ____________ BODY MATERIAL ____________

TORQUE SEQUENCE SKETCH

UPPER MAST DISCONNECT

INSTALLATION PROC: NAVSEA S 9425-AG-MMM-040-(U)

ANTI-SIEZE MATERIAL: N/A

SEALING COMPOUND: N/A

TORQUE DEVICE RANAGE /SERIAL NO.: N/A

CAL DUE DATE: N/A

RUNNING TORQUE: N/A

FINAL TORQUE (Required & Running Torque): N/A

THREAD PROTRUSION: N/A

PARTS REPAIRED: NONE

GASKET/O-RING DATA

SPECIFICATIONS: AN6230-B14

REF: NAVSEA S 9425-AG-MMM-040-(U)

NSN	EXP DATE

LOCKWIRED IAW: N/A

MICROMETER SERIAL NO: N/A

OTHER PARTS REPLACED

REF: NONE

SEALING SURFACE FINISH IAW: NAVSEA S 9425-AG-MMM-040-(U)

REASSEMBLY COMPLETED IAW: NAVSEA S 9425-AG-MMM-040-(U)

BLUE CHECK RESULTS: N/A

REMARKS

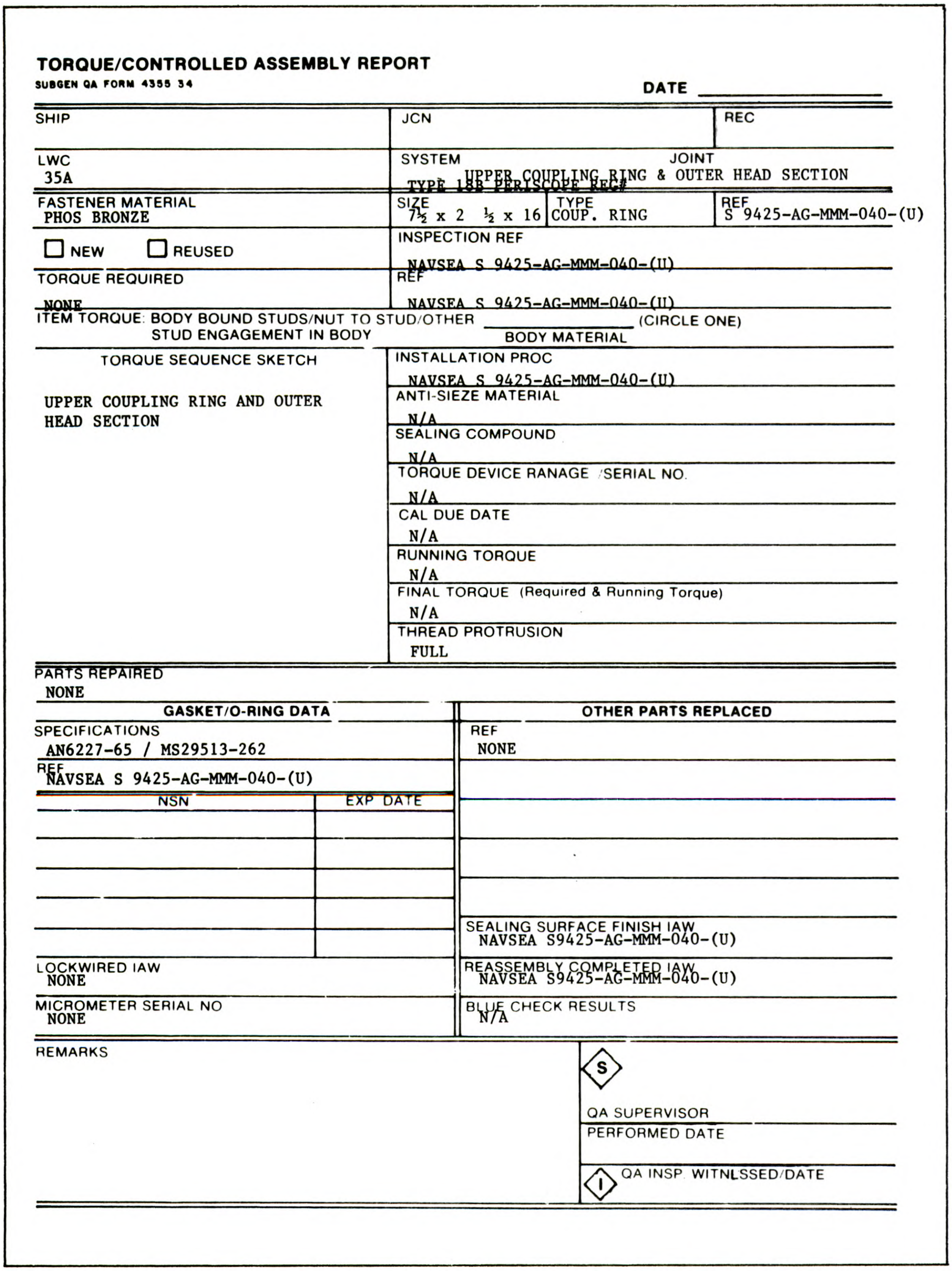
S QA SUPERVISOR

PERFORMED DATE

I QA INSP WITNESSED/DATE

148.419.3

Figure 7-6D.—QA Form 34 Torque/Controlled Assembly Report.



TORQUE/CONTROLLED ASSEMBLY REPORT

SUBGEN QA FORM 4355 34

DATE ____________

SHIP	JCN	REC
LWC 35A	SYSTEM TYPE 18B PERISCOPE REC#	JOINT UPPER COUPLING RING & OUTER HEAD SECTION

FASTENER MATERIAL PHOS BRONZE	SIZE 7½ x 2 ½ x 16	TYPE COUP. RING	REF S 9425-AG-MMM-040-(U)
☐ NEW ☐ REUSED	INSPECTION REF NAVSEA S 9425-AG-MMM-040-(U)		
TORQUE REQUIRED NONE	REF NAVSEA S 9425-AG-MMM-040-(U)		

ITEM TORQUE: BODY BOUND STUDS/NUT TO STUD/OTHER ____________ (CIRCLE ONE)
STUD ENGAGEMENT IN BODY BODY MATERIAL

TORQUE SEQUENCE SKETCH UPPER COUPLING RING AND OUTER HEAD SECTION	INSTALLATION PROC NAVSEA S 9425-AG-MMM-040-(U)
	ANTI-SIEZE MATERIAL N/A
	SEALING COMPOUND N/A
	TORQUE DEVICE RANAGE /SERIAL NO. N/A
	CAL DUE DATE N/A
	RUNNING TORQUE N/A
	FINAL TORQUE (Required & Running Torque) N/A
	THREAD PROTRUSION FULL

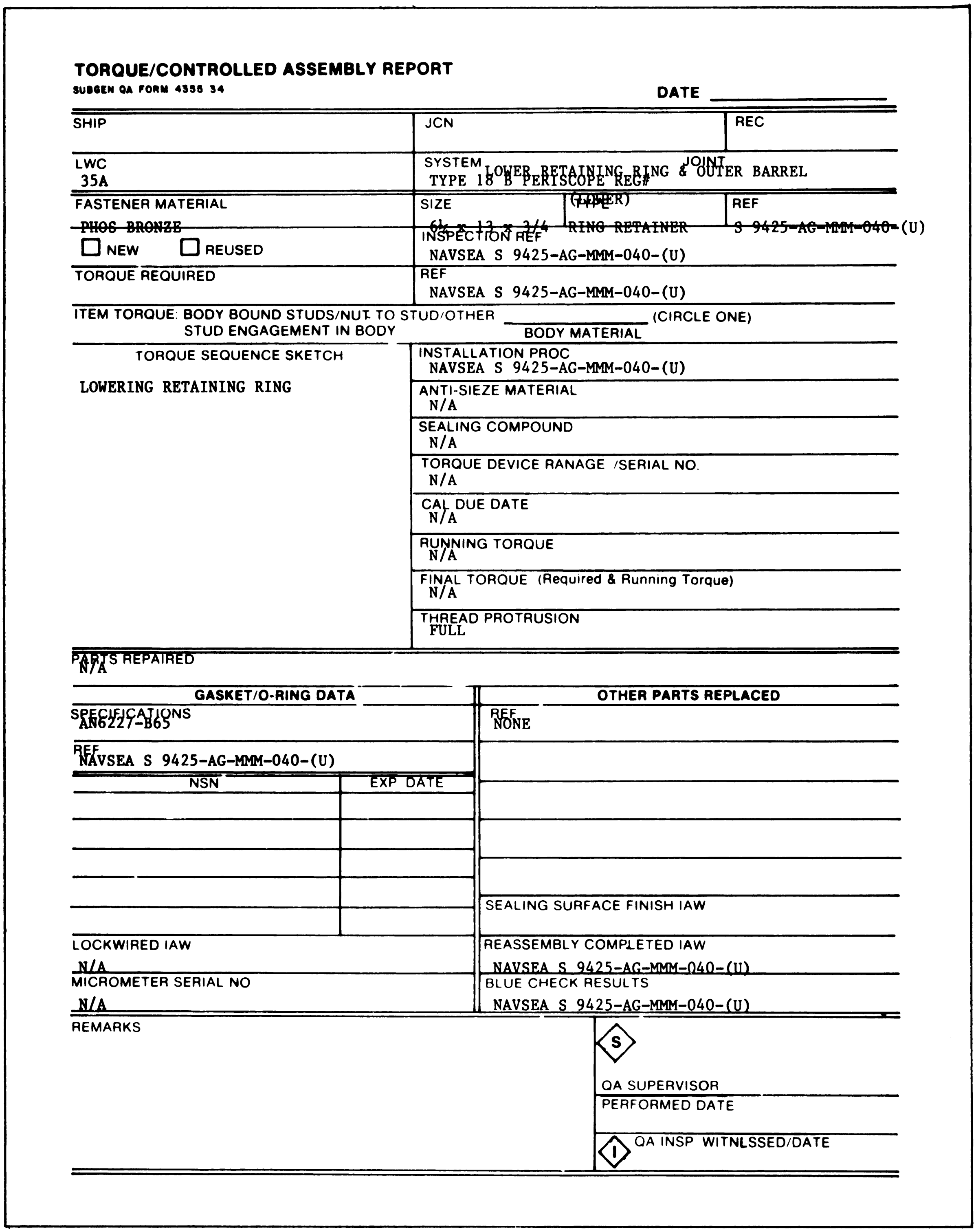
PARTS REPAIRED
NONE

GASKET/O-RING DATA		OTHER PARTS REPLACED
SPECIFICATIONS AN6227-65 / MS29513-262		REF NONE
REF NAVSEA S 9425-AG-MMM-040-(U)		
NSN	EXP DATE	
		SEALING SURFACE FINISH IAW NAVSEA S9425-AG-MMM-040-(U)
LOCKWIRED IAW NONE		REASSEMBLY COMPLETED IAW NAVSEA S9425-AG-MMM-040-(U)
MICROMETER SERIAL NO NONE		BLUE CHECK RESULTS N/A

REMARKS	◇S QA SUPERVISOR
	PERFORMED DATE
	◇I QA INSP. WITNESSED/DATE

148.419.4

Figure 7-6E.—QA Form 34 Torque/Controlled Assembly Report.



TORQUE/CONTROLLED ASSEMBLY REPORT

SUBGEN QA FORM 4355 34

DATE ____________

SHIP	JCN	REC
LWC 35A	SYSTEM TYPE 18 B PERISCOPE REG#	JOINT LOWER RETAINING RING & OUTER BARREL (LOWER)

FASTENER MATERIAL PHOS BRONZE	SIZE 6½ x 13 x 3/4	TYPE RING RETAINER	REF S 9425-AG-MMM-040-(U)
☐ NEW ☐ REUSED	INSPECTION REF NAVSEA S 9425-AG-MMM-040-(U)		
TORQUE REQUIRED	REF NAVSEA S 9425-AG-MMM-040-(U)		

ITEM TORQUE: BODY BOUND STUDS/NUT TO STUD/OTHER ____________ (CIRCLE ONE)
STUD ENGAGEMENT IN BODY BODY MATERIAL

TORQUE SEQUENCE SKETCH LOWERING RETAINING RING	INSTALLATION PROC NAVSEA S 9425-AG-MMM-040-(U)
	ANTI-SIEZE MATERIAL N/A
	SEALING COMPOUND N/A
	TORQUE DEVICE RANAGE /SERIAL NO. N/A
	CAL DUE DATE N/A
	RUNNING TORQUE N/A
	FINAL TORQUE (Required & Running Torque) N/A
	THREAD PROTRUSION FULL

PARTS REPAIRED
N/A

GASKET/O-RING DATA	**OTHER PARTS REPLACED**
SPECIFICATIONS AN6227-B65	REF NONE
REF NAVSEA S 9425-AG-MMM-040-(U)	

NSN	EXP DATE

SEALING SURFACE FINISH IAW

LOCKWIRED IAW N/A	REASSEMBLY COMPLETED IAW NAVSEA S 9425-AG-MMM-040-(U)
MICROMETER SERIAL NO N/A	BLUE CHECK RESULTS NAVSEA S 9425-AG-MMM-040-(U)

REMARKS	◇S QA SUPERVISOR
	PERFORMED DATE
	◇I QA INSP WITNLSSED/DATE

148.419.5

Figure 7-6F.—QA Form 34 Torque/Controlled Assembly Report.

special markings (or certification papers) that (1) verify its material and physical properties; (2) provide traceability to manufacturer, contract list, and lot; and (3) document the quality assurance system and test requirements applied to the item. Any SS or L1 item must be controlled/identified throughout the manufacturing/repair process, including installation, to meet the specifications required of the end product. Controlled material is placed in segregated storage and is identified by material markings and applicable QA forms.

SUBSAFE ITEMS

SUBSAFE items are controlled materials designed to ensure the integrity of submarines. This chapter lists some items that are SUBSAFE for type 2-D periscopes. These items are considered boundaries of the periscope. They include the head window assembly and the screws that hold it to the outer head and all the stuffing boxes on the eyepiece box, such as the illumination control stuffing box.

STOWAGE OF CONTROLLED MATERIAL

Controlled material, which is accepted after a receipt inspection, must be positively segregated to preclude inadvertent use. It should be handled in a manner that will prevent damage. During handling of controlled material, adequate records must be maintained from initial ordering to final issue. Controlled material records must be made available for audit by the QA officer, the supply officer, and others as required. Issue of controlled material must be controlled until its end use is assured. Controlled material end use is restricted to its specific applications.

PERISCOPE EVACUATION AND CHARGING

After a periscope has been reassembled, it must be tested to make certain there is no leakage in any one of the hermetically sealed areas. When a leak develops in any one of the sealed areas, gas leakage and "breathing" of the periscope occur during temperature changes. This enables water vapor to enter the periscope, which causes fogging of the internal optics. To correct this condition, you must locate and repair any leaks. After the leak has been located and repaired, you must evacuate the periscope by removing the moisture-laden nitrogen and refilling it with dry nitrogen. A dew-point test is made to ensure that the moisture content in the periscope is sufficiently low so that the optics will not become fogged. When these actions have been accomplished, the periscope is ready for installation in the submarine. In this section the state-of-the-art of periscope evacuation will be discussed. This discussion describes the use of equipment found aboard submarine tenders, but not available in all optical shops.

PRESSURE LEAK TEST

Soap tests, previously used to detect gas leaks, are no longer used. Instead small amounts of freon pressurized with nitrogen are used, because they give better test results. The following items are used to detect gas leaks:

Flow meter

Pressure gauge (2)

Regulator (2)

Freon

Nitrogen, technical

Halogen leak detector

To test for gas leaks, you should use the following procedure:

1. Connect test equipment as shown in figure 7-7.

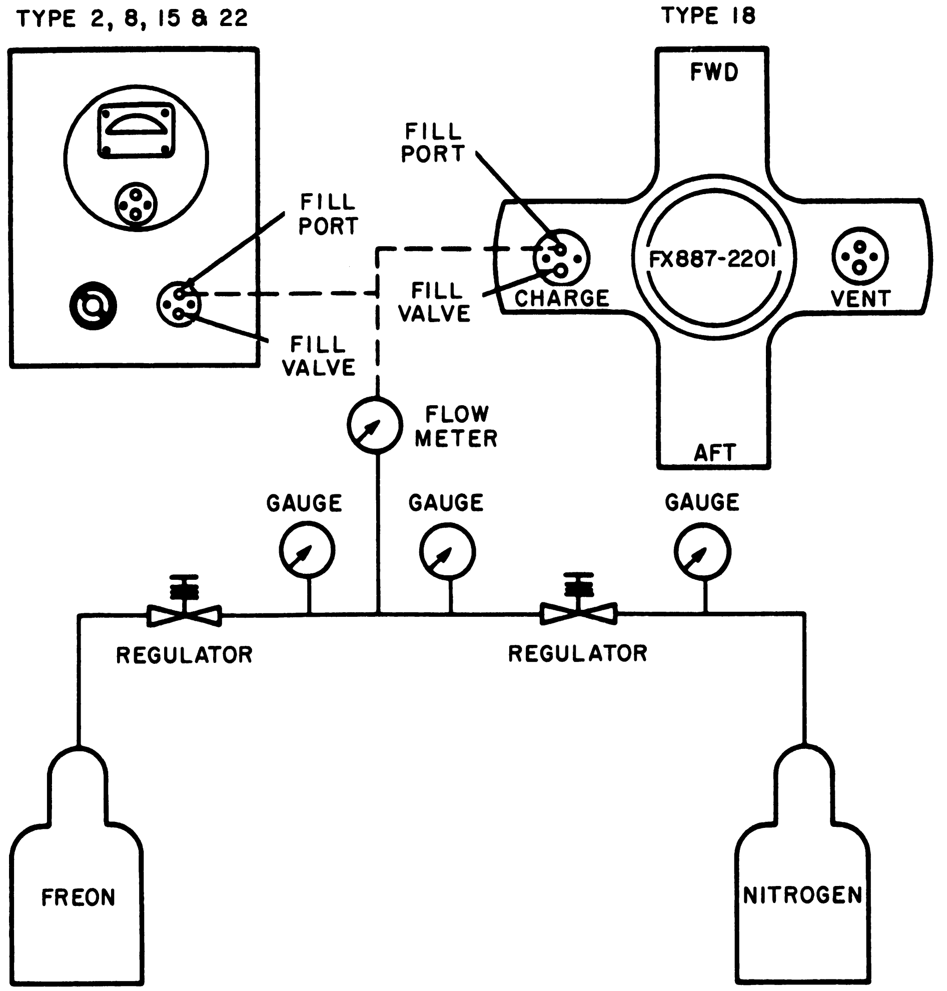
2. Open the freon filling valve and maintain the flow rate to less than 5 cubic feet/hour.

3. Pressurize the mast to approximately 2 psig of freon.

4. Close the freon filling valve and remove the pressure gauge and freon filling system.

5. Open the nitrogen filling valve and maintain the flow rate to less than 5 cubic feet per hour.

6. Pressurize the mast to approximately 7.5 psig of dry nitrogen and remove the charging system.



148.420

Figure 7-7.—Internal Low-Pressure Test Setup.

7. Using a calibrated halogen leak detector with an H-2 detector probe, monitor all hermetic seals.

8. If the halogen leak detector indication is within the specifications, replace the charging system and continue to slowly increase total pressure inside the periscope mast to +5 psig with nitrogen. Repeat step 7 at 10 psig increments to continue checking for leakage.

9. When 50 psig is reached, maintain for 30 minutes. Then repeat step 7 every 10 minutes.

10. Depressurize the mast of all residual nitrogen. Check for leaks at 10 psig increments as per step 7.

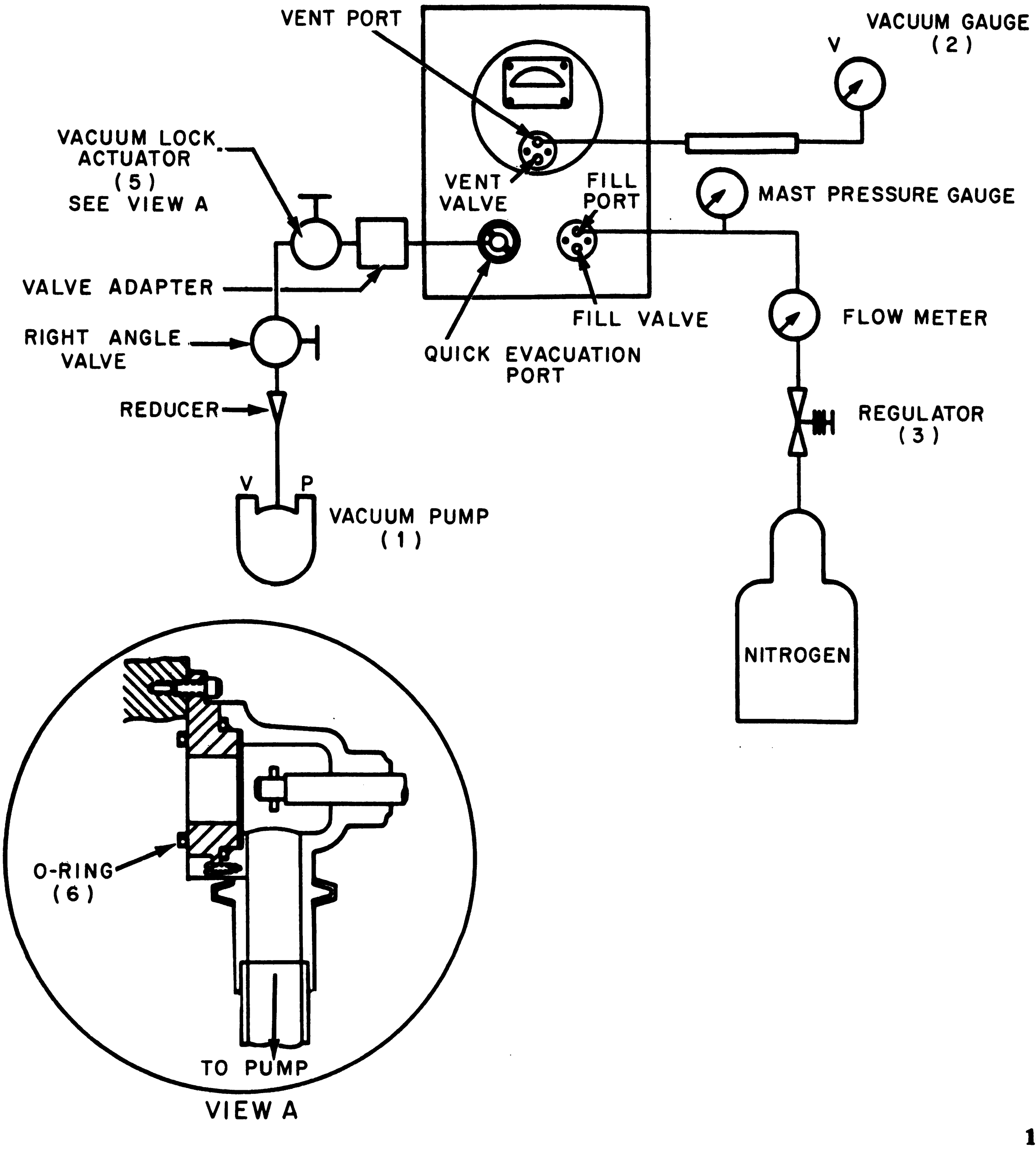
11. Close the air valve inlet plug when flow of gas stops and the pressure gauge indicates 0 psig.

12. Purge for 30 minutes (minimum) prior to performing periscope evacuation.

EVACUATION

This procedure is used to remove the moisture-laden nitrogen present in the mast assembly and refill it with dry nitrogen. The following evacuation/charging procedures must be performed prior to the dew-point test.

1. Remove the plug retainer from the quick evacuation port on the lower door of the eyepiece



148.421

Figure 7-8.—Type 2, 8, 15 and 22 Evacuation and Charging Setup.

box. Place an O-ring (fig. 7-8, view A) in the lower door recess.

2. Connect the valve adapter and vacuum lock actuator to the evacuation port as shown in view A of the figure. The handle of the vacuum lock actuator should be pulled back to provide maximum free passage of gas during evacuation.

3. Turn the handle of the vacuum lock actuator 20 degrees counterclockwise.

4. Start the vacuum pump (1) and energize the vacuum gauge (2).

5. Set the pressure regulator (3) to 15 psi.

6. Continue pumping until the pressure is reduced to less than 0.1 millibar.

7. Connect the periscope fitting (4) to the air valve inlet.

CAUTION

The periscope charging equipment must be connected at this point, otherwise the operator might open the charging valve and allow outside air to enter the periscope. This would further contaminate the periscope with wet air.

8. Attach three heat sensors to the periscope mast. Space them evenly along the tube.
9. Wrap the periscope mast with three heater blankets. Strap the blankets in place to provide uniform heating along the mast outer tube. Blankets should cover at least 70 percent of the periscope length.
10. Set the thermocoupler to 120° (40° C). Then energize the heater blankets.

NOTE: The periscope mast assembly is to be heated throughout the entire evacuation procedure.

11. Open the air valve inlet screw and allow the pressure to rise to between 25 to 50 millibars. Continue to cycle for 30 minutes. Close the air valve inlet screw.

12. Continue the evacuation until the vacuum gauge reads less than 0.02 millibar. Total time to reach this condition should be less than 8 hours.

13. Remove the heater blankets and sensor equipment.

CHARGING

To charge the periscope, perform the following steps:

1. Open the air valve inlet screw to allow a flow of nitrogen through the periscope. The flow rate should not exceed 5 cubic feet per hour.
2. Close the evacuation port by pushing in the vacuum lock actuator handle. Turn the handle clockwise to lock the sealing plug of the evacuation port in place. Deenergize the vacuum gauge (2).
3. Remove the valve adapter (4), the O-ring (6), and the vacuum lock actuator (5) from the evacuation port.
4. Screw the retaining ring into the evacuation port to secure the retaining plug. Store the O-ring with the valve adapter.
5. Continue filling with nitrogen until the pressure reaches 15 psi as indicated on the pressure gauge of the eyepiece box. Then close the air valve inlet screw.

DEW-POINT TEST

After the periscope has been filled for a minimum of 1 hour, perform a dew-point test as follows:

1. Connect the direct reading dew-point meter to the dew-point sampling valve port (fig. 7-8, view B).
2. Open the dew-point sampling valve to permit nitrogen to be bled from the periscope through the meter.
3. Let nitrogen flow for about 5 minutes to bleed moisture from the line and meter.
4. Take the dew-point reading from the meter and record it for future reference.
5. Disconnect the meter from the periscope.

PREPARATION FOR INSTALLATION

After all procedures described have been completed, follow the steps listed below to prepare the periscope for installation in the submarine:

1. Vent the pressure of the periscope until the internal pressure is 7.5 psi.
2. Reinstall any of the antennas that were removed for pressure testing, and make sure that all QA forms are completed.

APPENDIX I

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